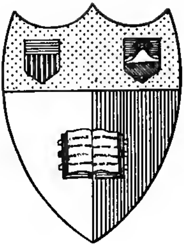
GA
12
G56

LOBE MANUAL



New York
State College of Agriculture
At Cornell University
Ithaca, N. Y.

Library

Cornell University Library

The original of this book is in
the Cornell University Library.

There are no known copyright restrictions in
the United States on the use of the text.

http://www.archive.org/details/cu31924081074019

GLOBE MANUAL

FOR USE WITH

STAND AND SUSPENSION GLOBES

Copyright, 1909, W. C. Co.

PREFACE

As this is an elementary work on the globe, no attempt is made at precise exactness in statement and definition: for example, the earth is regarded as a sphere; the celestial equator, a projection of the earth's equator outward against the starry dome; amplitude, latitude applied to the celestial sphere; date line, the 180th meridian; etc. 90° west means 90° west longitude; 40° north, 40 degrees north latitude. The sun is spoken of as moving, seeing the earth, etc. The earth is spoken of as moving in the direction of its noon-westward in its journey around the sun. Some problems and statements are true for the northern hemisphere only. A technical nomenclature is purposely avoided.

The pamphlet is divided into Five Parts. The teacher may begin with any one and follow in any order. While it has been prepared for use with the suspended globe, the work may be used with any globe. It is an advantage for each pupil to have a small 25 or 50-cent globe.

An attempt has been made to be rather comprehensive in topics but brief in treatment. Instead of giving the rules for the solution of problems, examples are given and processes described, leaving the teacher and pupils to make the rules.

Some repetitions occur from the fact that the pamphlet is divided into five parts. The publishers will be glad to have any errors pointed out that they may be corrected in other editions.

While this manual was written primarily to accompany the suspension or Hanging Globes, it is equally applicable to globes mounted on standards.

CONTENTS

PART I

Understand the Globe

Page.

Look at the globe 7
Northern and Southern Hemispheres 7
Eastern and Western Hemispheres 8
Land and water Hemispheres 8
Day and night Hemispheres 8
Direction earth rotates on its axis 9
Direction the earth revolves in its orbit around the sun 9
Ecliptic, The 10
Sun's vertical ray moves over 47 degrees of latitude 11
Parallels, some of them 12
Sun always in the south at noon 12
Meridians 13
International Date Line 13
Day begins where 14
Birth and death of days on earth 17
Zodiac, The 17
Signs of the zodiac 18
Railroads 20
Cables, Ocean 20
Isostherms 20
Hour circles 21
Meridians and time 21
Varying length of degrees of longitude 21
Analemma, The 22
Direction 23
Magnetic north pole 23
Standard time 23

PART II

Problems to be Solved by the Use of the Globe

1. To find the latitude of a place 25
2. To find places having the same latitude 25
3. To find the difference of latitude between any two places 25
4. To find the longitude of a place 26
5. To find the difference in longitude between two places 26
6. To find the shortest distance in miles between two places 26
7. To find any place, its latitude and longitude being given 27
8. To get location when at sea 27
9. To find what hour it is at any place, the hour at another being given 27

Page.
10. To find the difference of longitude, the difference of time being given 28
11. To find the length of a degree of longitude at any place........ 28
12. To find how fast you are carried from west to east per hour by the daily rotation of the earth on its axis........ 29
13. To find the antipodes of a given place........ 30
14. To find your perioeci 30
15. To find your antioeci 30
16. To find the ascii 30
17. To find the periscii 31
18. To find the sun's place in the ecliptic for any given day in the year 31
The zodiac, ecliptic, and analemma........ 31
19. To find the sun's declination on any day in the year........ 32
20. To find the places where the sun's ray is vertical on any given day 32
21. To find where the sun's ray is vertical, the day and hour at any particular place being given........ 33
22. To find the two days in the year when the sun's ray will be vertical to any given place within the tropics........ 33
23. To prove that the altitude of the north star equals your latitude wherever you are........ 33
24. To rectify the globe for any given place........ 34
25. To show that an unlimited number of great circless pass through any given place........ 34
26. To find the bearing of one place from another........ 35
27. To prove that the distance measured on a great circle connecting any two opposite points on the earth is 180 degrees........ 35
28. To prove that all great circles passing through a point also pass through the opposite point........ 35
29. To find the distance in miles from a given point opposite, say London, to any intervening point, say Costa Rica........ 35
30. To point through the earth in a straight line toward any given point 36
31. To find the direction in which a great circle passes through any two given points........ 37
32. To show the use of correction lines in original U. S. land surveys 37
33. To place the globe in the sunshine so that it will represent the natural position of the earth with reference to the sun........ 37
34. To show that twilight is shortest in the torrid zone........ 37
35. To find in what direction the rising sun will be seen on any day in the year........ 38
36. To find the time of sunrise or sunset for any day in the year........ 38
37. To find the parallel beyond which no ray is falling for any day in the year........ 39
38. To find the length of the longest day at any place within the frigid zone 39
39. To find the equation of time........ 40

PART III

Definitions

Definitions 41, 42, 43

PART IV

Facts and Explanations

Page.
Distances 44
Weight 44
Movement, Rate of 44
Seasons, The 44
Heat 44
Days and years, Kinds of 45
Moon, The 46
Moon, Phases of 48
Eclipses 49
Tides 49
Ellipse, An 51
Noon meridian, The 51
Sun, The 51

PART V

Making and Using a Blackboard Map of the Hemispheres

Making and using a blackboard map of the hemispheres 52-58

Illustrations

The birth and death of days 16
Orbit, zodiac, and signs 19
Finding distances in miles 36
Pointing in a straight line toward a place 36
The parallel beyond which no ray is falling 39
Parts of a circle and globe 41
Heat of vertical and oblique rays 44
Sun and star day 45
"Wet moon" and "dry moon" 47
The tides 50
Drawing the hemispheres 52, 55, 57

Tables

Signs of the zodiac 18
Standard time 24
Latitude and longitude 27
Number of miles in a degree of longitude 29
Kind of days and years 46
Problems in longitude and time 58

PART ONE

UNDERSTAND THE GLOBE.

Introduction. Many pupils have no image of the earth in space. To such many of the lessons mean nothing. As the pupil will have no better understanding of the earth than has the teacher, the first requisite is for her to familiarize herself with the globe. The use of the globe in teaching is not generally understood and its value is underestimated. Most globes are very dusty.

The Suspension Globe. The suspension form of mounting a globe is recognized by many educators as the most useful and practical form for school room use. Secure one of these excellent globes, mount according to directions, follow the instructions here given, and a new world will open up to your pupils. World Geography is now taught in the Fourth school grade, and yet most of the elementary geographies do not have even a hemisphere map.

This pamphlet is designed for use in all grades. The teacher must select that which is adapted to the advancement of her pupils.

Look at the Globe. Look at the globe; pull it down; turn it around, pull it as low as you can; raise it to the level of the eye. Get acquainted with it. It has many curious figures and lines upon it, but do not be afraid of it, for the purpose of these is readily learned.

Stand back and look at the globe again. You see one hemisphere and are conscious that there is another behind it. This is the way the earth looks to the sun and moon. Turn the globe in *any* direction and you still see a hemisphere, and are conscious that there is an opposite one that you do not see. How many hemispheres may one thus see? *An unlimited number.*

Northern and Southern Hemispheres. Suspend the globe so that the metallic meridian will be in a north and south vertical plane. *Standing north of the globe,* lower the north pole to the level of the eye, making the axis horizontal. What hemisphere do you see? *The northern hemisphere.* What circle bounds it? *The equator.* What lands does it cross? Does it cross more land or water? *Water.* Turn the 90th meridian west longitude uppermost, and imagine yourself at the north pole. Look down the 90th meridian. What direction are you looking? *South.* Across what country? *North America.* What direction at your right? *South.* Left? *South.* Back?

South. What is to your right? *Behring Sea.* Left? *British Isles.* In what direction are all countries from you? *South.* In what direction is north from you? Direction refers to the earth and there is no place north of the north pole; neither is there any east or west. Raise the pole to the altitude of the north star. What direction is up for you? *Over head.* How many degrees from your right to your left? *180.* From Chicago to London? *About 90.* How many degrees of longitude are in sight? *360.* How many hours of time? *24.* How many degrees of latitude? *90.* (Omit questions on lat. and long. if necessary till later.)

Turn the south pole toward you and repeat many of the questions. Locate the center of the southern hemisphere. *South pole.* Suspend the globe so that your feet would point toward the north star. What direction is down for you? *Toward the north star.*

The Eastern and Western Hemispheres. Stand west of the globe, turn the 110th meridian west toward you, axis of globe vertical, eyes on level with equator. What grand divisions of land do you see? *North and South America.* What ones do you not see? *All the others.* Stand back some distance and ascertain that the meridians 20 west and 160 east bound your view. What hemisphere do you see? *The one that geographers have agreed to call the Western hemisphere.* Walk up to the globe. What country north of you? *North America.* Southeast? *South America.* Southwest? *Australia.* Northwest? *Asia.* Is London nearer you east or west? *West.* If you can not see this, turn the 110th meridian uppermost, imagine yourself above it, and repeat these questions; but you should accustom yourself to being located otherwise than "on top" all the time.

Stand east of the globe, turn the 70th meridian east toward you, and repeat many of these questions. What meridians bound your view? *The same as before.* What hemisphere do you face? *The Eastern.*

Land and Water Hemispheres. Stand at some distance from the globe, facing London. What do you observe? *Nearly all lands.* What exception? *Australia.* What hemisphere do you see? *The Land Hemisphere.* Turn the globe until you face New Zealand. What do you observe? *Much water.* What hemisphere? *Water hemisphere.* Satisfy yourself that the boundaries of the two hemispheres are the same great circle. How long is that boundary? *25,000 miles.*. How far from New Zealand to that boundary circle? *¼ of 25,000 miles.* From London to that boundary circle? *¼ of 25,000 miles.* From London to New Zealand? *½ of 25,000 miles.* A place is 4,000 miles from London. How far is it from New Zealand? *8,500 miles.* Is it in the land or water hemisphere? *Land.* What line is the boundary of your vision when you face London from a distance? *The boundary between the land and water hemispheres.*

Day and Night Hemispheres. Face the globe with eye on a level with a point in the tropics or between the tropics. What do you see? *The Day Hemisphere, if your eye represents the sun.* What hemisphere is opposite? *The Night Hemisphere?* What line is the boundary between them? *The line bounding the vision of the sun's eye on earth.* What is the name of that great circle? *The day and night circle.* Do all the boundaries of hemispheres travel? *No; the ones named are stationary except the day and night circle.* How often does it pass around the earth? *Every day.* Locate its center. *The sun's vertical ray strikes the earth at one center; the other is the opposite point.* Locate the centers of the eight hemispheres named. The center of the night hemisphere is the point opposite the one where the sun's vertical ray strikes the earth. Rotate the globe and satisfy yourself that the boundary line of your vision travels around the globe. In what direction does the day and night circle travel around the earth? *Westward.* Do the centers of the day and night circles have any other movement? *Yes, they travel north and south between the tropics once each way every year.*

In What Direction Does the Earth Rotate on Its Axis? Lower the globe as far as you can, axis erect. Lay your watch on the north pole. Rotate the globe on its axis anti-clockwise; that is, in a direction opposite to that of the movement of the hands of the watch. This is said to be from west to east and gives you the direction of the rotation of the earth on its axis. Turn the axis in different directions, especially toward the north star; keep on rotating the globe until you get the direction firmly fixed in mind. Paste a bit of paper on Chicago for yourself and rotate globe.

If the earth rotates eastward when you are on the "top side," does it rotate westward when you are on the "bottom side"? No, always eastward, all day, day and night. Turn globe until a bit of paper is "on top," draw a vertical line on paper for your body, and a horizontal line across the vertical line for your arms. Mark the hand that points east. Suppose the figure is facing the globe head toward the north, then it is the right hand that is pointing eastward. Now rotate the globe on its axis and watch that hand to see if it points eastward all the way round; you will conclude that it does. You will also conclude that "east" is no point in the sky but is a direction relative to the earth's surface. The sun, moon, and earth all rotate on their axes in this same anti-clockwise direction.

In What Direction Does the Earth Revolve in Its Orbit Around the Sun? Place your watch on a boy's head and carry the globe around him anti-clockwise and you have the direction of the revolution. Look up at the real sun and try to imagine yourself going eastward, with the earth in its rotation on its axis, and the sun standing still; go once around in 24 hours. Again look at the sun at noon. Now try to see as far on the other side of the sun as you are from the sun and remember that the earth will be around to that point in six months. Now imagine your watch lying "on top" of the sun, remember which way the hands turn, and swing the earth around the sun in the opposite direction to the opposite point in the orbit. As you faced the sun, did you move the earth in its orbit toward your right or left?—toward your west or east? *West, as you face the sun, with back to north; in the direction your right hand points.* How would it be at midnight, 12 hours later? *Toward your left hand, if you still stand back to north, and that would be toward your east.* So when you see the sun, daytime, you are carried toward your west in the earth's orbit movement; try to imagine this and feel yourself swinging westward around the sun. It may be hard for you to feel that this same movement is toward your eastward point at night.

Place a lamp in the center of the room as the sun and carry the earth around it along the north, west, south, and east walls. Try it again, rotating the globe on its axis at the same time and inclining the north end of the earth's axis toward the north star. Try it again and cause the sun to revolve in the same anti-clockwise direction. Try it again and let a boy be the moon and revolve around the earth in anti-clockwise direction. Try it again and let the moon rotate on its own axis in anti-clockwise fashion. Try it again and let seven other pupils rotate anti-clockwise around the sun in the same plane as the earth does, these to represent the other planets of our solar system. In what direction does the solar system revolve? *Anti-clockwise.*

The Ecliptic. The path you followed around the school room represented the earth's actual path through space in its journey around the sun once a year. This path, or orbit, is called the Ecliptic. The plane in which this path is located is called the Plane of the Ecliptic. While the ecliptic is the earth's circular path around the sun, if you look at the real sun, of course it will appear to be located in the opposite point of the circular path, while in reality it is near the center. Look at the real sun and try to realize that it is in the center and that you are to swing entirely around it in a year, going in the direction of your (daytime) westward. Since the ecliptic is the sun's apparent path, you may think of it as the sun's path, just as you may think of the sun rising and the sun setting.

Of course the ecliptic is not on the earth, but for convenience it is represented on the globe. Of course the plane of the ecliptic cuts the earth into two hemispheres and cuts it at an angle of 23½° with the equator as shown. It remains at this angle all the time. Rotate the globe and see the ecliptic wabble. It should not move, of course, but is compelled to when drawn on the globe. Make a paper ecliptic and hold it at the one on the globe; now revolve the globe but hold the paper ecliptic so that it can not move—this gives a better notion of the ecliptic. Follow the ecliptic around the globe and remember it takes the earth and sun a year to make that same trip and that these bodies are always at opposite points in the path. Notice certain signs and marks on the ecliptic; we shall learn about these later.

How far from the north pole to the plane of the ecliptic? *Always 66½°.* How far from the earth to the ecliptic? *It is always in the ecliptic.* How far from the earth to the opposite point in the ecliptic? *About twice the distance to the sun.* How far from the sun to the ecliptic? *The distance from the sun to the earth.* Where, in the ecliptic, is the sun regarded as being? *In the point of the ecliptic opposite us (the earth).*

The Sun's Vertical Ray Moves Over 47° of Latitude and Thus Fixes the Boundaries of the Torrid Zone.

Let the chalk trough or window sills represent the ecliptic and carry the globe around in it, keeping the axis inclined 23½° toward the north. This will incline the equator 23½° to the chalk trough (ecliptic). Suppose you are located on the Arctic Circle where it crosses the 90th degree of west longitude, and turn the globe so that point will be uppermost. Place a pupil at the center of the room and let his eye be the sun, and let him report what he sees on the globe (earth) as you carry it around him. He may turn around at pleasure. Hold the globe on a level with his eye, inclined as directed. How far can he see over the north pole when you have the globe at south side of room? *23½°.* Then fix the location of the arctic circle, account for its location and for the width of the north frigid zone. What time of year is it? *It must be warm, for the sun shines far beyond the pole.* How far north of the equator does the vertical ray strike the globe? *23½°.* This is further evidence of heat in the northern hemisphere. This enables you to locate the Tropic of Cancer. You are now ready to move the globe onward in the ecliptic. How long will it take to go once around the room? *One year.* Which way will you carry it? *Anti-clockwise.* What time of year is it? *June 21st. The sun is at the Summer Solstice. Summer begins.*

Carry the globe one-quarter of the way round—to the east side of the room. Now where does the vertical ray strike the globe? *On the equator.* How far north and south does the pupil's eye (sun) see? *From pole to pole.* What about day and night over the whole globe? *They are equal, because the eye sees half of every parallel.* Give date. *September 22d.* Be certain to keep the axis inclined to the north 23½° all the time. *Autumnal Equinox. Autumn begins.*

Carry the globe through another quarter of the ecliptic—to the north side of the room. How about the vertical ray? *It strikes the globe 23½° south of the equator, or 47° south of the Tropic of Cancer.* Account for the location of the Tropic of Capricorn and for the width of the torrid zone. How many degrees south has the vertical ray traveled in six months? *47.* What zone has it crossed? *Torrid.* Locate the tangent ray south. *23½° beyond the south pole.* Give date. *December 21st.* Give reason for location of Antarctic Circle. Is the larger part of the southern hemisphere in darkness or in light? *In light and there is summer in that hemisphere.* The sun sees less than half of every parallel in the northern hemisphere, hence the long nights and winter. This is the date of the *Winter Solstice.*

Move the globe onward another quarter, to the west side of the room, find sun's vertical ray on equator again, days and nights equal, and spring beginning. Date March 20th, *Spring or Vernal, Equinox.* How long between the two equinoxes? *Six months.*

Carry globe to place of starting, south side of room. When are our days longest? *At the summer solstice, because sunlight never covers as much of our parallel at other times.* Shortest? *At winter solstice, because sunlight never covers so little of our parallels at other times.* Equal? *At the equinoxes, because sunlight covers just half of our parallel at such times and at no other.*

If you did not rotate the globe on its axis in carrying it along the ecliptic, repeat and rotate it; your former conclusions are still true. Name two causes of seasons. *The inclination of the earth on its axis and revolution around the sun.* Carry the globe around again and observe that, from the globe, the pupil's eye (sun) is always in the opposite point of the ecliptic from the globe. Try it again and note the time when the pupil can see the entire Arctic Circle; also Antarctic Circle. Try to get the notion that the real ecliptic is the path of the earth in the starry dome and that the wabbling one on the globe is not the real one.

Give dates when the pupil at the center of the room saw both poles; also when the sun's ray was vertical at the equator. How often each year is the sun's ray vertical at the equator? *Twice.* How often will every place on earth have equal days and nights? *Twice a year, as often as the pupil saw each pole at the same time.* Except at the equator, when the days and nights are equal at any one place (say Chicago) are they equal at all other places on earth at that same time? *Yes. But they are* ALWAYS *equal at the equator.*

Some of the Parallels. Suspend the globe at the Arctic Circle. Note that latitude is marked on the meridian, and that the meridian forms a GREAT CIRCLE because it divides the globe into two hemispheres.

By the meridian, give the latitude of the Tropic of Cancer. *23½° north.* Arctic Circle. *66½° north.* Tropic of Capricorn. *23½° south.* Antarctic Circle. *66½° south.* South Pole. *90° south.* The equator. *0°.* How far apart are the parallels drawn on the globe? *10°.* Are the degrees of latitude marked on any other meridian? *Yes, on the 180th meridian east or west.* How far from the parallel 20° north to the Arctic Circle? *66½°—20°=46½°.* How many degrees in the equator? *See by the globe: 180+180=360.* How many in every other parallel? *See by the globe that they all have the same, 360.* What about the length of the parallels? *They decrease in length from 25,000 miles at the equator to nothing at the poles.* Show this on the globe.

The Sun Always in the South at Noon. Place a boy at center of room, place globe on south side of room, paste a bit of paper on Illinois for yourself, incline the axis northward, turn globe so the paper will face the boy's eye (sun). What time is it? *Noon, because sun's vertical ray is somewhere on the meridian that passes through your place.* As you face the sun in what direction are you looking? *Toward the equator and therefore south.* Carry the globe to the east side of room, paper facing the sun. In what directin do you face when looking at the sun? *Toward the equator and therefore south.* Carry the globe to the north, west, and other points. Repeat the questions and you will get like answers. So, the sun is always in the south, or toward the equator, at noon, or when it is over your meridian.

On carrying the globe onward, you will observe that the sun is much higher above the horizon plane of the paper (your horizon) at some points than others, but the sun is always toward the equator, south, at noon. In fact the sun's altitude will vary from day to day. It will also be observed that the bit of paper is not always "on top" at noon.

Meridians. Note the metallic meridian on the globe and its opposite one, the two making the metallic meridian circle. How far apart are the two metallic meridians? *180°.* What other meridian has the degrees of latitude marked upon it? *The 180th.*

Count the meridians drawn on the globe. *24.* How many degrees apart are they? *360÷24=15°.* How many hours around the earth? *24, the same as the number of meridians on the globe.* Then how far apart are the meridians on the globe? *One hour; they are also 15°.* Then what does one hour equal? *15°.* See where the meridian of London is marked and how. *It is marked zero on the equator.* Then what is the longitude of that meridian? *It has none.* What name is written on that meridian on the globe? *The meridian of Greenwich.* There is an observatory at Greenwich which is very near London. What other names are given this meridian? *Prime meridian and Zero meridian.* What degrees of longitude are numbered on the equator? *Every 10th degree.* How often do these fall on the meridians drawn on the globe? *On every second meridian.* Why? *Because 10 exactly divides every even multiple of 15.*

Why are the degrees of longitude marked on the equator of the globe? *Simply for convenience.* Are they marked on the equator in maps? *No.* Then where are they marked on maps? *At the top and bottom.* Why are they so marked? *Simply for convenience.*

What is the noon meridian? *It is the meridian on which the sun's vertical ray falls. It travels around the earth with the sun once every 24 hours.*

What is time of day recorded from? What do you say for afternoon? *P. M.* For forenoon? *A. M. So, time of day is recorded from noon, 12 hours each way.* Every hour in the day is recorded from noon, judging from the way you make the record; as 9 A. M. and 9 P. M. When I meet you in the morning and ask the time of day and you reply that it is 9 o'clock, you think 9 after midnight but you will record it 9 before noon, 9 A. M. But it must not be understood that 9 A. M. means nine hours counted back from noon, for time is actually counted from noon to midnight and from midnight to noon. So 9 A. M. means nine hours after midnight, but it is the "9" that is before noon and not the "9" that is after noon. So the record is made twelve hours each way from noon; the record is made from noon only.

The International Date Line. We may refer to this simply as the Date Line. It is near the 180th degree of longitude.

Suppose this is Monday noon and that the sun is keeping the earth's day and noontime. It records Monday noon for its vertical ray. As it moves westward the next 24 hours it will repeatedly record Monday noon and come back to us the next day recording Monday noon. Something is wrong for it is Tuesday noon for us. Evidently it should have added a day some place. Start at Monday noon again and you go along with the sun and you, too, keep recording Monday noon and come back to us saying Monday noon. But we tell you that it is Tuesday noon. You, too, should have added a day some place on your journey. Instead of keeping up with the sun, suppose you take a year to go around. Start Monday noon with the sun. When we have our Tuesday noon you will be some miles west of us and will have to wait for the sun to come to your Tuesday noon. That is, you will have lost a few minutes; or, your day is a little more than 24 hours long. By the time you return in a year you will have had 365 of these losses, which will amount to a day, the same as if you had kept up with the sun. So again you should have added a day at some place on the trip. The International Date Line is the place where you and the sun should have added a day. So, add a day on crossing the Date Line going west. You will find the Date Line named on the globe.

If you go east and the sun west and both go at same rate, you will meet the sun half way round and have another noon in 12 hours. You will be back to our meridian Tuesday noon, but you will say it is Wednesday noon. You should have subtracted a day on crossing the date line going east. By custom, navigators add or subtract a day near the 180th meridian. There is no date line by treaty—only by custom.

Theoretically the 180th meridian is the Date Line; the one on the globe is correct in actual practice. By treaty it might be located on any line, but mid-Pacific is a convenient place. Twelve hours from Greenwich is also convenient.

Why is the Date Line crooked? *Look at the Aleutian Islands. Naturally they all wish to keep the same time, but this makes the Date Line crooked, as you will observe.* The same is true in other instances. What kind of time does the eastern cape of Asia keep? *Note it is Asiatic.* When it is Monday noon at Aleutian Islands, what is the time in eastern Asia on same meridian? *Tuesday noon as shown by the date line.* Why are the degrees of latitude marked on the date line rather than on the prime meridian? *Owing to the absence of land on the date line, the figures are more legible on that line.*

Do people that live near the date line have to add or subtract a day? *Not unless they cross the date line.* If they crossed the date line a dozen times a day would they have to add and subtract a day as often? *Yes, the same as you would have to add or subtract an hour every time you cross the line bounding a standard-time section.* What difference in time between two places a mile apart, but on opposite sides of the date line? *About one day.* Which has a day later? *The one west of the date line.* Illustrate all this by the globe.

Where Day Begins. Suppose this is Monday noon for you. When did it begin to be Monday for you? *Last night at midnight.* Did Monday begin for London sooner? *Yes.* For Asia still earlier? *Yes.* Well, who had Monday first?—that is, where on earth was Monday born? The people just west of the date line had it first and it was born so soon after Saturday that no time elapsed between midnight Saturday night (or midnight Sunday morning) and midnight Monday morning. After it was born just west of the date line a moment after midnight, how much of the earth's surface was then having Monday? *A narrow strip just west of the date line.* What happened to this strip? *It began to widen westward, thus pushing the midnight line entirely around the earth.* What was that midnight line the boundary of? *The boundary between places having Sunday and those having Monday.* Twelve hours after the birth of Monday the vertical sun will have reached the date line and the boundary between Sunday and Monday will have reached London, the prime meridian. This moving boundary line between the old and new day is always 12 hours ahead of midday, or noon meridian. Then does Monday begin just west of the date line and gradually cover the earth? *Yes.* When will the whole earth have been covered by Monday? When the sun, or mid-day meridian shall have reached London. How many days on earth are there at the same time? *Always two, except for an instant when the sun is on the meridian of London, or Greenwich.* Where is there always a new day being born? *Twelve hours ahead, west, of the noon meridian.* Where is the new day first born? *Just west of the date line.* Where is there always an old day dying? *Twelve hours behind, east of, the noon meridian.* Is 12 hours east of the noon meridian and 12 hours west of it on the same meridian and just opposite the sun? *Yes.* Then is there an old day dying and a new day being born just opposite the sun whether it is on your noon meridian or not? *Yes.* Does the birth and death take place on the same line? *Yes, the new day begins where the old one leaves off.* Where does the old day die last? *Just east of, or rather at the date line.* Where will Monday finally cease to exist on earth? *Just east of the date line.* Where is the sun when the old day finally dies? *Over the meridian of London.* Where is the sun when the new day is first born? *Over the meridian of London, because the new day is first born when the old day finally dies on earth.*

If you lived near the date line when would your new day begin? *Twelve hours before noon, the same as anywhere else.* When London has her noon, has she the same day as every other place on earth? *Yes.* Is that true of any other meridian except the prime meridian? *No.* How old is Monday 12 hours east of London noon? *Twenty-four hours.* How old is Monday 12 hours west of London noon? *Just born, a moment old, just beginning.* When Monday dies just east of the date line, how old is Tuesday just west of the date line? *Twenty-four hours, and also ready to die at that place—just a day difference as you have learned.*

The western boundary of the new day moves westward around the earth and this is the same as saying, the eastern boundary of the old day moves westward around the earth for the two boundaries are the same line; but what about the eastern boundary of the new day and the western boundary of the old day? This boundary does not move, but remains fixed at the 180th meridian. Two days meet at every place on earth once every 24 hours; but along the 180th meridian two days always meet. How much time between the two days where they meet? *Less than can be assigned, except at the 180th meridian, where the difference is 24 hours.* Could a man stand in two days at once on the 180th meridian? *I suppose so.* Could a man stand in two days at once at the poles? *I suppose so.* What difference in time, if any, would the man's two feet have at the 180th meridian? *Twenty-four hours.* Which would be a day older? *The one to the west of the date line.* What difference would

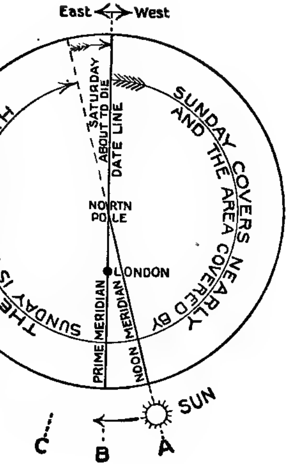


FIG. I

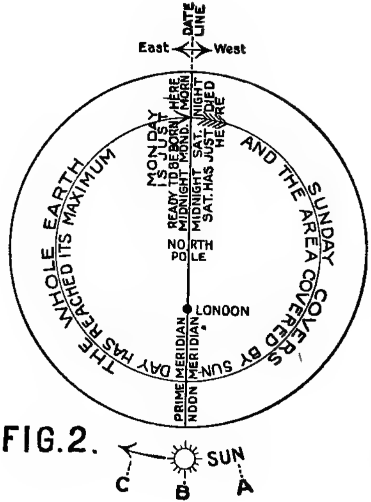


FIG. 2.

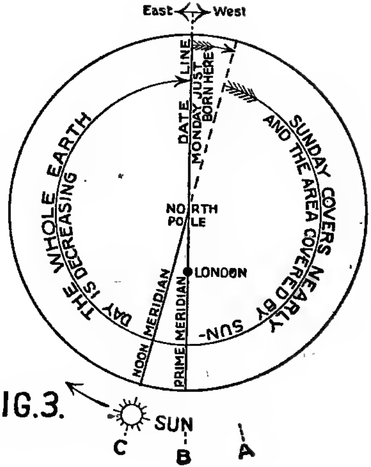


FIG. 3.

the man's feet have if he stood at one of the poles? *Any difference he chose to make less than 24 hours.* Use the globe in explaining all this.

In answering these questions, you had better use the theoretical date line, the 180th meridian.

THE BIRTH AND DEATH OF DAYS ON EARTH.

(A CHAPTER OF INTEREST TO TEACHERS.)

Study the changes that take place as the noon sun passes from A to C.

Place yourself at London for this discussion.

Fig. 1 shows Saturday about to die; that its final disappearance is just east of the Date Line, that Sunday is soon to cover the whole earth and that the area it covers is increasing, and that it is just before noon at London.

Fig. 2 shows the facts an instant later; that Sunday covers the whole earth and covers the maximum area, that Saturday is dead and Monday unborn, and that it is exactly noon at London.

Fig. 3 shows the facts an instant later; that Monday has just appeared on earth, that its first appearance is just west of the date line, that Sunday still covers nearly the whole earth, but is decreasing in area, and that it is just afternoon at London.

Obviously Fig. 1 (Saturday night at midnight just east of the date line—that is, Saturday about to die on earth) may change to Fig. 3 (Monday morning at midnight—which is the same as saying Sunday night at midnight—just west of the date line) in an instant.

The midnight meridian is always a death-and-birth line, with only an instant between death and birth on its two sides, except when it crosses the Date Line, when there is 24 hours' difference in its two sides.

That is, Monday first appears on earth the moment Saturday dies on earth, and Sunday is very much alive at the time this death and birth are taking place, for it is then covering the whole earth.

When Monday noon at London, Monday covers the earth and yet there is 24 hours' difference between the two sides of the date line; the beginning and ending of Monday meet at the date line and, of course, there is 24 hours' difference in the two extremes of Monday.

A new day finally ends on earth the same place it begins—at the date line—but 48 hours after it begins. After a new day has first appeared on earth, the earth has to revolve twice to get rid of it. It requires 24 hours for a day to cover the entire earth and 24 more to uncover it.

It is 48 hours from the time a day first appears on earth just west of the date line, until it finally leaves the earth just east of the date line.

The Zodiac. Look up into the blue dome and think of the sun in its apparent journey from east to west through our southern skies. Remember that its path does not change, although the sun seems high in summer and low in winter—it is the earth inclination that causes this deception. All the planets travel along near this same stationary path of the sun, not varying more than 8° on either side of it. The earth and sun do not vary at all from the ecliptic. The ecliptic is a line, but the zodiac is a band 16° wide—8 on either side of the ecliptic. This band, or zone, is divided into 12 parts called signs. How many degrees in a sign? *360÷12=30° in a sign.* While a sign is 30° in length, astronomers have designed certain figures, or characters, to represent these degree signs, called "Signs of the Zodiac."

Look at the ecliptic on the globe and find the signs marked 10, 20, 30; 10, 20, 30; 10, 20, 30, etc. Also find the characters that represent the degree signs and are placed near each "30." No two of these 12 characters are alike. These characters are located at the beginning of each sign; that is, just after the "30."

There is a certain group of stars in each of the 12 divisions of the band, or zodiac; that is, in each of the 30-degree sections of the zodiac.

The western part of each sign is called the first part of each sign and the "30" stands at the last part. The "30" stands on the last part of the sign and the character on the first part of the next sign.

The first part of Aries is, as you will see on the globe, at the vernal equinox, March 30th. This means that the sun is vertical at this point and therefore at this latitude entirely around the earth on March 20th.

Which way does the sun travel along this ecliptic we are examining? *Anti-clockwise;* so lay your watch near the north pole and find that would be toward the east on the globe. Locate Aries again where the ecliptic crosses the zero meridian. Which way will the sun move to enter the proper sign? *East and enter Taurus.* How many degrees did you move the sun through Aries? *30.* So move the sun on around through the 12 signs to the place of starting.

When the sun is in Aries, where is the earth? *In the opposite point, Libra.* Find it. But usually you are to think of the sun as being in the ecliptic rather than of the earth being there.

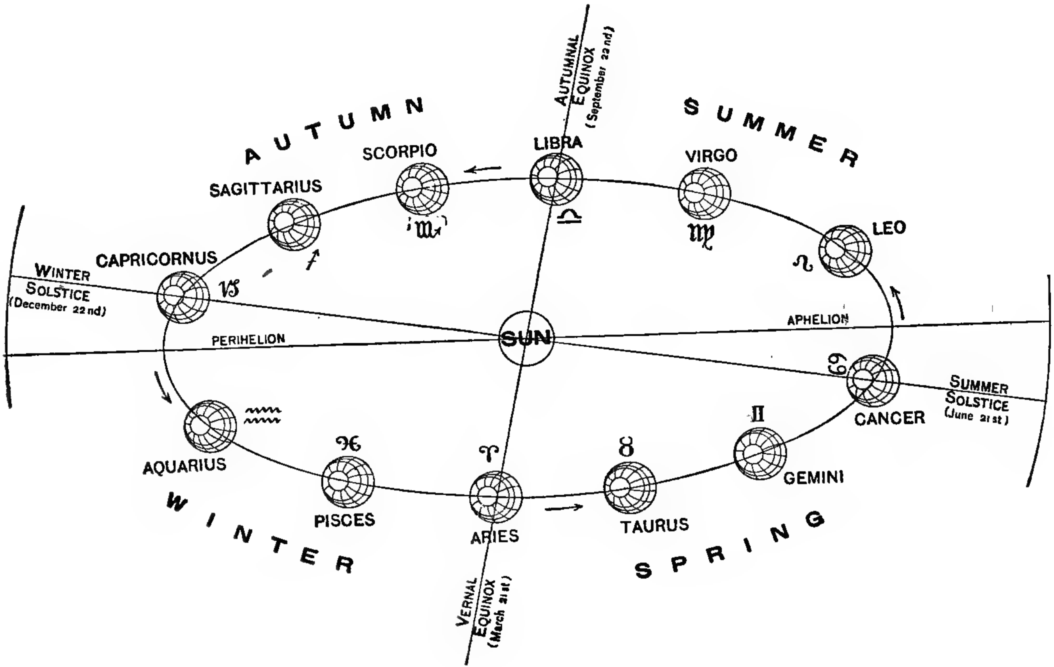
The sun and earth chase each other round and round in the ecliptic, both in the same direction and 180° apart.

SIGNS OF THE ZODIAC.

Northern Signs: Find them on the globe in the ecliptic north of the equator. Note that these are the months when the sun's vertical ray is north of the equator.

Spring Signs:

1. Aries (Ram)—From March 21 to April 20.
2. Taurus (Bull)—From April 20 to May 21.
3. Gemini (Twins)—From May 21 to June 21.


AUTUMN
SUMMER
AUTUMNAL EQUINOX (September 22nd)
SCORPIO
♏
SAGITTARIUS
♐
LIBRA
♎
VIRGO
♍
LEO
♌
CAPRICORNUS
♑
WINTER SOLSTICE (December 22nd)
PERIHELION
SUN
APHELION
SUMMER SOLSTICE (June 21st)
♋
CANCER
♊
GEMINI
♒
AQUARIUS
♓
PISCES
♈
ARIES
♉
TAURUS
WINTER
SPRING
VERNAL EQUINOX (March 21st)

Summer Signs:

4. Cancer (Crab)—From June 21 to July 23.
5. Leo (Lion)—From July 23 to August 24.
6. Virgo (Virgin)—From August 24 to September 23.

Southern Signs: Find them south of equator.

Autumn Signs:

7. Libra (Balance)—From September 23 to October 23.
8. Scorpio (Scorpion)—From October 23 to November 23.
9. Sagittarius (Archer)—From November 22 to December 22.

Winter Signs:

10. Capricornus (Goat)—From December 22 to January 20.
11. Aquarius (Water-Bearer)—From January 20 to February 18.
12. Pisces (Fishes)—From February 18 to March 20.

Of course, the next day after March 20 would be March 21, the day we started. That is when these 12 signs are arranged in a circle, as on the globe, you pass from the 12th into the 1st. Notice this on the globe.

Try to imagine the sun passing eastward in this ecliptic and making the circuit in a year. As it passes through the signs, of course it will pass through the groups of stars in each sign.

In the preceding figure note the earth in its orbit, the signs of the zodiac along that orbit or ecliptic, with sun at the center. But instead of seeing the earth as it is, try to place the sun at a point opposite the earth. The seasons, solstices and equinoxes are also indicated.

Answer from the figure, then locate on globe. Locate the earth June 21st. In what sign? *Cancer.* Season? *Beginning of summer.* Do you find the tangent ray passing beyond the north pole to the Arctic Circle as it should? *Yes.* Where would the sun appear to be if you were looking at it from the earth? *In the opposite sign, Capricornus, December 22, where the earth will be in 6 months.* So the sun is in the winter signs when we are in the summer. Do you see by the figure where the sun would appear to be?

Railroads. Notice on the globe the dark crooked line crossing Russia and connecting St. Petersburg and the Sea of Japan. What is it? *Look beneath the circle on the globe, that contains the manufacturer's name, and you will find that it is a railroad.* See if New York, Chicago, and St. Louis are similarly connected. *Yes.*

Cables. What are the dotted lines that cross the seas? Look as before and see that they are cables. Does one connect San Francisco, Hawaii, Guam, and Japan? *Yes.*

Isotherms. What are the narrow blue lines that encircle the globe in such an irregular manner? Look as before and find that they are January isotherms. What one crosses Ohio, Indiana, Pennsylvania and Illinois? *The 30° isotherm.* Trace it around the globe.

An isotherm locates places having the same temperature. What are the narrow red lines that encircle the globe in a similar manner? Look as before and note that they are July isotherms. What one passes near Washington, D. C.? *The 80° isotherm.* Trace it.

Hour Circles. How many degrees apart are the meridians drawn on the globe? *15.* How many hours apart? *One.* Then what may these meridians be called? *Hour circles.* Count the spaces between the meridians and see if there are 24 to correspond with the 24 hours of the day. How long will it require the sun to move from one meridian to the next? *One hour.*

While these meridians are really hour circles they are not numbered from one to twelve twice for one day as is the clock, so the face of a clock is placed at the north pole. Find it. It is movable and its divisions correspond with the meridians as you see. This is called the hour circle, or time disk, or time dial. It is used to find the difference of time between two places, the length of days, etc. The real hour circles are the same as our meridians but projected outward against the hollow dome of the skies.

The Meridians and Time. When 7 o'clock at Philadelphia what is the time at New Orleans? Count the inter-meridian spaces and find it to be 6 o'clock. Earlier because west. Place the 7 of the time dial on the meridian of Philadelphia and find that the meridian of New Orleans gives you six. Which city does the sun reach last? *New Orleans.* Then which will have later time? *Philadelphia.* Get answer by solution. (90—75)÷15=1 hour difference in time.

When 8 a. m. at Philadelphia what is the time at Carson City, Nevada? Place 8 of the time dial on the Philadelphia meridian and trace the Carson City meridian to the time dial and find it is 5 o'clock. Count the inter-meridian spaces to see if there is 3 hours between these cities. Give arithmetical solution. (120—75)÷15=3 hours, difference in time. Subtract because west. 8—3=5 o'clock.

Varying Length of Degrees of Longitude. See the globe and notice the figures on the 30th meridian west longitude. What do they mean? These figures give the length of a degree of longitude for the various latitudes in geographical miles. Notice that the numbers become smaller from the equator either north or south.

How could you calculate the length of a degree of longitude in statute miles at the equator? Divide 25,000 by 360. 69 1-6 is the correct answer. What is given on the globe at the equator? *60.* In other words, 1 degree equals 60 geographical miles or 69 1-6 statute miles. How long is a degree of latitude 10° north or south of the equator? Look on the 30th meridian west and find it to be 59 geographical miles. How about 40° north? *46 miles.* At the poles? *Nothing.*

Run two fingers along two adjacent meridians from the equator to the poles and notice that the distance between the fingers gradually reduces to zero as you approach the poles. Now the *number* of degrees between the fingers remains 15 during the journey, but evidently something shortens, and it must be the length of the degree, and so it is. The number of miles between the fingers become fewer and fewer as you approach the pole, but the mile does not change its length. The degrees do not change their number but their length as the fingers approach the pole. The miles do not change their length but their number as you approach the pole.

It is the degrees of longitude, not of latitude, that vary in length.

The Analemma. What is the large figure 8 crossing the equator on the globe and extending from tropic to tropic? *It is called the analemma.* It is a diagram, or scale, drawn on the globe, showing the latitude where the sun's rays are vertical on any day of the year, thus showing the sun's declination, or latitude, on any day in the year. It also gives the equation of time. Notice that it has the months and days upon it. The signs of the zodiac might be placed on the analemma, but they are arranged in their places along the ecliptic instead. The equation of time means the difference between sun time (sun-dial time) and clock time (average sun time).

On what days of the year is the sun's vertical ray falling on the equator? Look on the analemma and find that the equator crosses it on March 20th and September 22d. These are the answers.

Where is the sun's ray vertical on June 21st? *Find the latitude of June 21st on the analemma to be 23½° north.* That is, on the entire Tropic of Cancer on that date, the sun's vertical ray is falling: not on each point all day, but at some time within the day. Try it for December 21st and other dates. After you find the latitude, you may locate that degree of latitude on the metallic meridian and find in what countries or places the sun's ray is vertical by rotating the globe and noting the places that pass under that particular degree on the meridian.

The analemma also shows the distance in latitude the direct rays of the sun pass over during any month. That is, it shows that the sun passes north or south more rapidly in some months than in some others. For instance, the sun at some dates seems to stand at the same place at our noon for several days, or even a month, as in June, while at other times it seems to climb up higher rapidly from noon to noon. The analemma shows the facts. Notice how much longer space north and south some months occupy than others. At what two periods does it almost take a month to "turn round," according to the analemma? *June and December.*

According to the metallic meridian and analemma, what latitude does the sun's vertical ray pass over in October? *10°.* In January? *5* or *6°* In June and December? *2* or *3°.* During what winter month would the sun be at about the same height every day at our noon? *December; it would only vary 2 or 3°.* During what summer month? *June.*

Why does the sun not change its altitudes much during these months? *Because it is at its highest or lowest points above or below the equator at these dates and is making the change from ascent to descent or vice versa.* For example: Suppose it went south 2 degrees and north 2 degrees, that is only 2 degrees of latitude passed over—at any other place than at the turn it would have counted 4 degrees of latitude. There are other reasons for the difference also.

The analemma also enables you to equate time. A good watch and the sun do not keep the same time. They are together but four times a year. That is, your clock and sun dial will be together four times a year. The greatest difference between the clock and sun is on the 2d of November, when the sun is 16 min. 20 sec. fast, while on the 11th of February it is 14 min. 20 sec. slow. This difference between clock and sun is called the equation of time. So, sun time varies but has been averaged up and given over to the clocks to keep. Given clock time and an analemma, you can find sun time. The analemma gives the equation, or difference, of the two kinds of time for every day in the year.

Notice that the horizontal line has 20 divisions on either side of the center; these are minutes slow or fast. No use to make this line longer, because the sun is never quite 17 min. fast and never quite 15 min. slow.

What does "Clock after the sun" mean on the analemma? *It means clock slow or sun fast for the months named on the right side, or the east side of the analemma.*

What is the equation in time, or difference in clock and sun, on November 2d? Lay the straight edge of a piece of paper parallel with the meridian that divides the analemma but passing through the point indicated for November 2d. Notice that it crosses the horizontal minute scale between 16 and 17. That is, the clock is over 16 minutes slow. Try it for other dates. Use the metallic meridian instead of the paper if you prefer; or use compasses and measure the distances from the meridian that divides the analemma.

The Magnetic North Pole is 90° west longitude and 70½ north latitude. Find it on globe. What direction from you? *The magnetic needle points toward it.* How would the needle point at the magnetic north pole? *Down.* How far is it from the north pole? *$90° - 70\frac{1}{2}° = 19\frac{1}{2}°$.* Name the states that are on the same meridian as the magnetic north pole.

Direction. This has reference to the earth only, not to the stars. We do not say the north star is east or west of another star, but we may say it is north of us (with reference to direction on earth); or the sun south of us at noon (with reference to direction on earth). If we say the sun rises in the east, we mean in the direction of an east line on earth, but our same east line describes a circle in the skies every day and is constantly changing its direction with reference to the stars but not with reference to the earth.

When the sun shines in our north window at sunrise or sunset we say it is north of us, but we know it is never over 23½° north of the equator and we are probably further north than that.

Standard Time, or Railroad Time. Travelers and railroad people found it inconvenient to keep their time with the sun and so made their own and called it standard time. They divided the United States into belts and chose a meridian for the center of each belt, or one as near the center as practical. They also chose meridians 15° apart, beginning with the meridian of Philadelphia. The standard time meridians and names of the inter-meridian standard time belts are as follows:

Central Meridian	**City on Central Meridian**	**Name of the Belt**
75th	Philadelphia	Eastern Time
90th	St. Louis	Central Time
105th	Denver	Mountain Time
120th	Santa Barbara, Cal.	Pacific Time

How far apart are these cities? *15° from city to city, or one hour.* How do sun time and railroad time compare at these standard meridians? *They are the same.* How is it on either side of any standard meridian? *The people have the same standard time as the meridian.* How do (average) sun time and standard time compare on either side of any one of these meridians? *The sun time is fast or slow at the rate of 4 minutes for each degree measured from the meridian.* Are the boundaries between belts midway between every two successive standard meridians? *No.* This was found to be impracticable. The boundaries between standard time belts are very irregular. At El Paso, Texas, Central and Pacific time meet, thus crowding out the Mountain time belt entirely.

How much does the traveler change his time in crossing a boundary? *One hour; but it is two hours at El Paso.* Name a city on the boundary between Eastern and Central time. *Pittsburg.* What standard of time would a place on the boundary keep, such as Pittsburg? *The standard time of both belts and they would be an hour apart, unless they agree to keep one or the other.* They may also keep sun time, which would differ about a half hour from either. Some cities use standard time for railroads and sun time for other purposes, as Detroit.

Use the globe in working out an understanding of most of this.

PART TWO

PROBLEMS TO BE SOLVED BY USE OF THE GLOBE.

MAKE YOUR RULES FROM THE SOLUTIONS GIVEN.

1. To find the latitude of a place.

What is the latitude of central Ohio, Indiana and Illinois? *Find by the figures on the meridian that it is about 40° north.* What places have no latitude? *The meridian says the equator.* Revolve the globe and see that all places on the equator have no latitude. How great a latitude may a place have? *90°.* What two places have that? *The poles.*

Through how many degrees of latitude does a meridian extend? *180.* A meridian circle? *360.* Do all places that have the same latitude have the same length of day and night? *Yes.* Seasons? *Yes.* Climate? *No.*

What is your latitude? Say it is 40° north. What do you mean by 40°? *The line that connects you with the center of the earth cuts the plane of the equator at the center of the earth at an angle of 40°.*

Is the shortest distance from the equator to the poles along the meridians? *Yes, if you follow the earth's surface, otherwise a straight line passing through the earth is the shortest.*

2. To find places having the same latitude.

What places have the same latitude as central Indiana? Find by the meridian that central Indiana is in 40° north latitude; revolve the globe and name the places that have the same latitude: *Central Spain, central Caspian Sea, and northern Corea.*

By the same method find places that have about the same latitude as London, New York, Chicago, New Orleans and your own town.

3. To find the difference of latitude between any two places.

What is the difference of latitude between New York and the Cape of Good Hope? By the meridian, get the latitude of each place and add, because on different sides of the equator. *74°.* Between New Orleans and Madrid? *10°.* Find the latitude of each and take the difference, because both on the same side of the equator.

What places have the greatest difference in latitude? *The poles.* What places have no difference in latitude? *Those on the same parallel.* How great a difference of latitude might two places have?

Any number not exceeding 180°. On what meridian of the globe besides the metallic meridian is latitude marked? *On the 180th.*

4. To find the longitude of a place.

What is the longitude of New Orleans? *About 90° west.*

Beginning at the zero meridian on the equator, count the meridians west to the 90th degree west longitude. Note that longitude is marked on the equator 180° east and west from the zero, or London meridian. Note that longitude is marked on the equator every 10°, but that a meridian is drawn every 15°, or an hour apart.

What places have the greatest longitude? *Those on the 180th meridian.* What places have no longitude? *Those on the prime meridian.* Are all clocks at the same time on the same meridian? *Yes (unless they keep railroad time).* Do all places on the same meridian have sunrise at the same time? *No, except twice a year.* Noon at the same time? *Yes.* Equal days and nights? *No.* Use globe and explain all this.

What is your longitude? Say it is 80 west. What do you mean by 80? The plane of your meridian cuts the plane of the prime meridian at an angle of 80°. This angle lies along the axis of the earth.

Are any parts of Greenland and Iceland in the same longitude? *Yes.* (See meridian.) What is the longitude of Rome? *12° 27′ east.* Edinburg? *3° 11′ west.*

5. To find the difference in longitude between two places.

What is the difference in longitude between Rome and New Orleans? *90° west+12° 27′ east=102° 27′.* Using the meridian, the equator will give you these longitudes, approximately, for these two cities. Add, because on different sides of the prime meridian. If the cities had been on the same side of the prime meridian, you would have subtracted. In adding, if the sum be over 180°, you subtract the sum from 360 to get the longitude of the shortest longitude route between the two places. Explain this on the globe.

What is the difference in longitude between a place 10° east of the 180th meridian and one 10° west of the 180th meridian. *170+170=340. 360—340=20°.* Verify on globe. How many degrees of longitude are you from the 180th meridian? *Subtract your longitude from 180.* What if you go in the opposite direction? *Add your longitude to 180.* What is the greatest difference in longitude two places may have? *180°.*

6. To find the shortest distance in miles between two places.

What is the distance from London to Constantinople? Measure the distance with a flexible quadrant having degrees marked thereon, or with a string drawn from one city to the other; lay the string on the equator and you will find the distance about 22°, then multiply by 60 to get the geographic miles (1320), or better by 69 1-6 to get the English miles (1,522).

How far is it from Paris to St. Helena? *66°=4,565 miles.* How far are you from the North Pole? From Cape Farewell? From Panama?

7. To find any place, its latitude and longitude being given.

Suppose you were shipwrecked at 40° north latitude and 30° west longitude; locate yourself on the globe. Rotate globe to the longitude as marked on the equator, find the latitude on the meridian, and you will find that you are near the Azores.

Suppose a wireless message locates a vessel at 65° north latitude 15° west longitude; locate it on the globe and find it is on the east coast of Iceland.

Find the places having the following latitudes and longitudes:

Latitude.	Longitude.	Answer.
20° 00′ N	90° 00′ W	Yucatan.
50° 00′ N	125° 00′ W	Vancouver.
29° 57′ N	90° 00′ W	New Orleans.
41° 54′ N	12° 27′ E	Rome.
50° 6′ N	5° 54′ W	Lands End.
19° 25′ N	99° 5′ W	Mexico City.

8. To get location when at sea.

First, to get the longitude. Suppose you started from London at noon two days ago and set your watch by the London time. To-day the sun shines for the first time since you started. When it crosses your noon meridian you take out your London-time watch and it says 1 P. M. for London. What do you know? You have sailed west one hour, or 15°, into earlier time. That is, the difference in time between you and London is one hour, which equals 15°.

Second, to get your latitude. With his sextant the navigator will measure the altitude of the sun at noon and compute his latitude. Having your latitude and longitude, you can locate yourself on the globe.

Suppose you sailed from New York at noon yesterday. To-day noon by the ship's clock, called a chronometer, your watch gives 12:15 P. M. What do you know? You have sailed ¼ of 15° east but you do not yet know how far north or south.

Suppose a telegram be sent from Philadelphia, 75° west longitude, at 11 A. M., to Santa Barbara, 120° west longitude. When will it arrive? *120—75=45. 45÷15=3 hours earlier, or 8 A. M. Longitude at sea is ascertained by the same process, as you observed above, except you have the difference in time and want the difference in longitude.*

9. To find what hour it is at any place, the hour at any other being given.

When noon at Denver what is the time at Philadelphia? *Set the 12 of the time dial on the meridian at Denver, and observe that the meridian of Philadelphia leads to 2 o'clock at the time dial for that city.*

When midnight at Philadelphia what is the time Denver. *10 P. M. Time west is earlier, as shown on the time dial.*

Set the time dial for *your* meridian and hour, and observe the time for the opposite meridian; also the time at different places.

10. To find the difference of longitude, the difference of time being given.

15° of longitude=1 hour of time, or 60 minutes.
1° of longitude=4 minutes of time.

A captain sails west from London, carrying the time of that city. Some days later at noon the London watch gives 9 A. M. The difference in time is 3 hours, what is the difference of longitude? *3 times 15 is 45°, difference of longitude.* What is his longitude? *45° west. If his latitude is found to be 60° north, his globe will show him to be in sight of Greenland.*

The difference in time between central Australia and central Arabia is 6 hours. What is the difference in longitude? *6 times 15 is 90°.*

The difference in time between central Oregon and central Australia is 7 hours, as shown by the time dial at the north pole. Place 12 noon at Oregon for Monday, count west and find Australia is 7 before 12, or 5 A. M.; but you crossed the date line going west and must add a day, making the time 5 A. M. Tuesday. What is the difference of time between these two places? *The difference between 12 noon Monday and 5 A. M. Tuesday. There are 12 more hours in Monday, plus the 5 in Tuesday, making the real difference 17 hours. To get the real difference of time in hours between two places, count so that you do not cross the date line; count the long way if necessary. This gives 17 for the answer to the last problem. Since no day crosses the date line, you may find it more convenient not to do so in finding the difference in time. Multiply difference in time by 15 for difference in longitude.*

When 11 P. M. Monday at Santa Barbara, what is the time at Philadelphia? *Count the hour meridians or use the time dial and find 3 hours the answer. 3 hours after 11 P. M. gives 2 A. M. Tuesday for Philadelphia. Multiply the difference in time by 15 for difference in longitude.*

If you prefer, in counting time on the globe, you may always count westward, but add a day if you cross the date line. If the difference in longitude is over 180, subtract it from 360 for shortest route.

11. To find the length of a degree of longitude at any given place.

Run the compass points up any two adjacent meridians on the globe and observe that they come together at the pole. As there are 15° of longitude between these two meridians at any parallel, the degrees must shorten as you approach the poles.

What is the length of a degree of longitude in central Illinois? *One way to tell is to look on the 30th meridian west, where the answer is given in geographical miles. But you could tell in another way. With a quadrant or a string measure the distance between the 75th and 90th meridian through central Illinois, apply string to equator to find the length in equator degrees, as in problem 6. Mul-*

tiply this by 69 1-6 to reduce to English miles and divide by 15 to get length of one degree in English miles.

Find the length of a degree of longitude at the following places:

Paris, where 15°=9¾° on equator; 9¾×69 1-6÷15=45 English miles.

Washington, where 15°=11½° on equator; 11½×69 1-6÷15=53 English miles.

Cape Farewell, where 15°=7½° on equator; 7½×69 1-6÷15=34½ English miles.

To find the length in Geographical miles multiply by 60, instead of 69 1-6.

A TABLE.

SHOWING HOW MANY MILES MAKE A DEGREE OF LONGITUDE IN EVERY DEGREE OF LATITUDE.

Deg. Lat.	Geo. Miles	Statute Miles	Deg. Lat.	Geo. Miles	Statute Miles	Deg. Lat.	Geo. Miles	Statute Miles
1	59.99	68.99	31	51.43	59.13	61	29.09	33.45
2	59.96	68.95	32	50.88	58.51	62	28.17	32.40
3	59.92	68.91	33	50.32	57.87	63	27.24	31.33
4	59.85	68.83	34	49.74	57.20	54	26.30	30.24
5	59.77	68.74	35	49.15	56.51	65	25.36	29.15
6	59.67	68.62	36	48.54	65.81	66	24.40	28.06
7	59.55	68.48	37	47.92	55.10	67	23.45	28.96
8	59.42	68.38	38	47.28	54.37	68	22.48	25.85
9	59.26	68.15	39	46.63	53.62	69	21.50	24.73
10	59.09	67.95	40	45.96	52.85	70	20.52	23.60
11	58.89	67.72	41	45.28	52.07	71	19.53	22.47
12	58.69	67.49	42	44.59	51.27	72	18.54	21.32
13	68.46	67.23	43	43.88	50.46	73	17.54	20.17
14	58.22	66.95	44	43.16	49.63	74	16.54	19.02
15	57.95	66.64	45	42.43	48.78	75	15.53	17.86
16	57.67	66.32	46	41.68	47.93	76	14.52	16.70
17	57.38	65.99	47	40.92	47.06	77	13.50	15.52
18	57.06	65.62	48	40.15	46.16	78	12.48	14.35
19	56.73	65.24	49	39.36	46.26	79	11.45	13.17
20	56.38	64.84	50	38.57	44.35	80	10.42	11.96
21	56.01	64.41	51	37.76	43.42	81	9.38	10.79
22	55.63	63.97	52	36.94	42.48	82	8.35	9.59
23	55.23	63.51	53	36.11	41.53	83	7.31	8.41
24	54.61	63.03	54	35.27	40.56	84	6.27	7.21
25	54.88	62.54	65	34.41	39.58	85	5.22	6.00
26	53.93	62.02	56	33.53	88.58	86	4.18	4.81
27	53.48	61.48	57	32.68	37.58	87	3.14	3.61
28	52.97	60.93	68	31.79	36.57	88	2.09	2.41
29	52.48	60.35	59	30.90	35.54	69	1.05	1.21
30	51.96	59.75	60	30.00	34.50	90	0.00	0.00

12. To find how fast you are carried from west to east per hour by the daily rotation of the earth on its axis.

Rotate the globe on its axis and satisfy yourself that the people at the equator are carried eastward 25,000 miles a day, you less, and the poles not any.

How fast are the Parisians carried eastward? *In Problem 11 we learned that the people of Paris are carried 9¾ equator degrees in one hour; this multiplied by 69 1-6 equals 675 miles per hour. In the same problem we learned that one degree at Paris is about 45 miles long. But there are 15° in an hour. 45 multiplied by 15 gives about the same answer as above.*

How fast are the people of Washington, D. C., carried east? *By the last problem and by the 30th meridian west on the globe, one degree at that place is about 63 miles long; 15° or one hour would equal 15 times that.*

How fast is the equator carried eastward? *69 1-6 multiplied by 15 gives about 1,000 miles per hour.*

How fast are the poles carried eastward? *0 times 15 equals 0.*

13. To find the antipodes of a given place.

Who are your antipodes? *A straight line passing from you through the center of the earth will emerge on the opposite side at your antipodes. The soles of your shoes will face the soles of their shoes. When you and they both point down, you point in a straight line toward each other. If a hole were drilled from you through the center of the earth and out at the opposite point from you, your antipodes might look through it and see you. Your antipodes have days and nights, seasons, latitude and longitude the opposite of yours.*

Who on earth are farthest from you? *Your antipodes.* How many miles from you are they? *½ of 25,000.* How many degrees of latitude from you? *Twice your latitude.* How many degrees of longitude are they from you? *½ of 360.*

If you are at 40 north and 80 west, locate your antipodes. *Pass from your meridian across either pole to the opposite meridian to the place where this meridian crosses your parallel of latitude, but south of the equator. This gives the place as southwest of Australia. Another method would be to go 180° east or west and then south on that meridian to your opposite latitude; 100° east longitude, 40° south latitude. Simply turn the globe 180° and then run down to your latitude but south of the equator.* Where is the antipodes of the north pole? *At the south pole.* What is the antipodes of the prime meridian? *The 180th meridian.* Are the Chinese your antipodes? *Probably not.*

14. To find your perioeci, or those who live 180° of longitude from you but have same latitude as you.

If you are at 40° north, 80° west, locate your perioeci. *Simply follow your meridian up over the pole and down the opposite meridian to your latitude in central China. Use the metallic meridian and try it.* Are the Chinese your perioeci? *Yes.* Try it again, setting the 12 of the time dial for your meridian, and then using the other 12 on the dial to locate the opposite meridian. Have your perioeci your latitude? *Yes.* Longitude? *No.*

15. To find your antioeci, or those who have your longitude but opposite latitude.

If you are at 40 north and 80 west, locate your antioeci. *Simply run down your meridian to your opposite latitude and you will find that they must be in a ship.*

16. To find the ascii, or those who have no shadow at noon.

This is the same as finding where the sun's rays are vertical on any given date and will always be within the tropics.

17. To find the periscii, or those whose shadow moves in a circular direction around them.

This is the same as locating any one in sight of the midnight sun and will be within the polar circles. Does your shadow ever pass through more than a semicircle? *Yes.* When is it the shortest? *At noon on June 21st.* The longest? *At sunrise and sunset.* If you were on the north pole on March 20th, where would you see the sun all day? *In the horizon.* Would the sun and your shadow describe a circle? *Yes.* Does your shadow now pass anti-clockwise? *No.* Would it if you were at the north pole? *No.* South pole? *Yes.*

18. To find the sun's place in the ecliptic for any given day in the year. Something of the zodiac, analemma and ecliptic.

Consult the globe or almanac for names of signs and characters representing them.

TABLE.

60″ in 1′
60′ in 1°
30° in 1 s. (Sign).
12 s in 1 c. (Circle). 12×30=360° in one circle.

See "Analemma" in index to Part First of this pamphlet, also see "Zodiac" in same index.

Notice that on the globe the ecliptic crosses the equator at the meridian of Greenwich, and that "30", or the end of a sign, is located there, as well as the character for Aries (♈ Ram), which is at the beginning of the sign Aries. Follow this same latitude to the analemma and find the date on the analemma to be March 21st. So the sun enters the sign Aries on March 21st, at the beginning of spring.

Start at the beginning of Aries and follow the ecliptic eastward 30° to the beginning of the next sign, Taurus, ♉. Find the latitude by the meridian to be about 11°, turn the meridian to the analemma and note that 11° gives you the date April 20th for the sun's entrance into Taurus (♉, Bull). By the same method find date when the sun enters each sign. How long will the sun be in the sign Aries? *From March 21 to April 20.*

Now reverse this process. Given August 26th, locate the sun in the ecliptic. Find the sun's declination for August 26th on the analemma with the meridian (10° north), then rotate globe and note that it cuts the ecliptic at two places instead of one. Which one locates the sun for August 26th, is the question. Start on the ecliptic for the beginning of Aries again and observe that the sun moves northward through March, April and May, and then starts southward through June, July and August (21st), when it is at the equator again. Evidently the sun passes over the 10th parallel of north latitude soon after March on its way northward and so August 26th must be found on the 10th parallel after it has started southward. So, if you will remember that the sign Aries is at March 20th, you can easily ascertain whether you are to take the point where the sun crosses the parallel of the sun's vertical ray on the date given, in its northern journey or in its southern.

Notice on the ecliptic of the globe that the sun passes northward rapidly in some months compared with others; and that the same is true in its southward journey. Measure with meridian. Compare Aries with the next two signs as to latitude crossed.

Locate the sun's vertical ray on May 20th. The analemma says it is on the 20th parallel north some place; and where that parallel crosses the ecliptic says it is at one of the two crossing places. As May is not far from March it must be at the point in the ecliptic where the sun crosses the 20th parallel going northward—at the 29th degree of the sign Taurus, the next sign after Aries.

Locate the sun on October 19th. The analemma locates the sun's vertical ray for October 19th at 10° south. Start at Aries and go eastward six months, or to the opposite point, September 21st. As October is the next month, pass on a little further to the point in the ecliptic crossed by the 10th parallel of south latitude.

If you will remember where the sun is March 20th, at the beginning of Aries, you will have no trouble to locate the sun for any date.

Notice the small divisions of the ecliptic; these are degrees and there are 360 of them. As there are 365 days in a year, the sun moves a little less than the length of one of these degrees every day in its eastward course in the ecliptic.

You see by the ecliptic why six of the signs are called southern and six northern. In going north across the torrid zone the sun is said to be ascending; in going south, descending.

19. To find the sun's declination on any day in the year.

The declination is the distance in degrees north or south of the equator.

What is the sun's declination on May 20th? By the analemma find the latitude of the sun's declination for May 20th to be 20° north. This is the answer. The sun's vertical ray will follow the parallel that is 20° north around the earth on May 20th. See if the analemma gives you 23½° north latitude for the sun's vertical ray on June 21st. You know it should. Try it for September 21st and December 21st.

20. To find the places where the sun's ray is vertical on any given day.

By the analemma and the metallic meridian find the sun's declination as before; note the latitude on the meridian, revolve the earth and note all places passing under that latitude on the meridian. The sun's ray is vertical at all these places on the given date. The places will be within the tropics because the sun's vertical ray never gets beyond them; and the sun's ray will be vertical twice a year at every place within the tropics—once in its northern journey across the torrid zone and once in its southern.

Where are the sun's rays vertical on December 21st? By the analemma and the metallic meridian find that all places on the parallel of 23½° south latitude will have the vertical ray at noon December 21st.

21. To find where the sun's ray is vertical, the day and hour at any particular place being given .

Of course, when the sun's ray is vertical at any particular place, it will be vertical at every other place on that parallel some time within the same day, but it will be vertical at only one place on that parallel at any given hour.

Suppose that you are 40 north 80 west at 11 a. m. March 20th. Where is the sun's ray vertical at that hour? You know it is one hour or 15° east of you, for it is an hour later than your time.

Find the declination on the analemma for March 20th to be the equator, then turn east 15° from your longitude and you find the place in northern Brazil.

Suppose you are at the same place as in last problem at 2 p. m. June 21st. Where is the sun's ray vertical at that moment? Evidently noon is 30° west of you. By the metallic meridian and analemma find the declination and latitude for June 21st. Rotate the meridian 30° west from you and locate the place at the lower end of Lower California.

Suppose the time were 11 p. m.? Evidently the noon meridian has passed on 11 hours west of you. So count 11 hour circles west from you for the meridian and solve as before. Near Formosa. If you prefer, set the 11 on the time dial for your meridian, count west 11 hours, and solve as before.

At 4 p. m. same date, at Madrid, where is the sun's ray vertical? *Trinidad.*

22. To find the two days in the year when the sun's ray will be vertical at any given place within the tropics.

On what two days in the year will the sun's ray be vertical at Calcutta? By the metallic meridian find the latitude of Calcutta to be 22° north. Turn the analemma to the meridian and find that 22° north gives you June 10th and July 4th as the answer. As it is difficult to read the day-marks on the analemma, you may miss it a few days.

23. To prove that the altitude of the north star equals your latitude wherever you are.

That is, suppose you are in Illinois 40 north and 90 west; to prove that the north star is 40° above your northern horizon.

How far from your horizon to your zenith? *90°.* Does the north star seem nearer your zenith or northern horizon? *Zenith, but it is not.*

Place yourself at the equator, and let the north end of the earth's axis point toward the north star. Where would you see the north star? *In the horizon.* Leave the globe as it is and move up to the north pole. Where would you see the north star? *In the zenith.* How far did you move? *90° north from the equator.* How far did the north star move? *90° toward the zenith from the horizon.* That is the north star rises one degree for every degree you move north from the equator; in other words, its altitude is your latitude.

Now move to latitude 40 in Illinois and suspend the globe at that point; the altitude of the north star is 40°.

24. To rectify the globe for any given place.

To rectify a globe means to place it in the same relative position as the earth; that is, with the axis of the globe parallel with the axis of the earth; equator with equator; parallels with parallels—that is, to make the globe right.

Suppose you are in Illinois, 40 north and 90 west. Rectify the globe for yourself. You think you are "on top," so, suspend the globe at 40 north and 90 west, and you will be "on top," and the globe will be rectified for you. The axis must be in a north and south plane with north pole inclined northward.

The axis of the globe now points toward the north star, and its equator, axis, and parallels are parallel with those of the earth.

Rectify the globe for your actual place in the same way.

If the globe were inclined 23½° north, would you be on top? *No, not unless you are at a certain point in the Arctic Circle.*

Rectify the globe and test it at night to see if the axis seems to point toward the north star.

Suppose you were at Terra del Fuego, how would you rectify the globe for yourself? *The same way; suspend the globe at that place, place the axis in a north and south plane, with north pole inclined toward the north star.*

When the globe is rectified for one place is it rectified for any other? *No.* To rectify the globe for any particular place, you must be at that place or at the latitude of the place. Suppose you are at Boston, 42½° north, rectify the globe. Rectifying the globe means placing the zenith of that place 90° from the horizon of that place. When the globe is rectified it is said to be *set.*

Why do not globe makers mount them so the north pole points toward the north star? *They would if everybody lived at the same place.* If everybody lived at 40 north and 90 west, or any other longitude, how would globes be mounted? *The globe's axis would be inclined 40° to the north instead of 23½°, if it were then rectified for everybody; but it might still be left inclined 23½, owing to the inclination of the axis to the plane of the ecliptic.*

25. To show that an unlimited number of great circles pass through any given place.

A great circle divides the earth into two equal hemispheres.

Show that an unlimited number of great circles pass through your place. Cut a string the length of the equator on the globe. This string is the length of a great circle. Pass it around the globe in many directions but always through your place in great circles and you will find that it is the right length and locates a great circle each time.

Choose any other place and show that the same is true.

(The Johnston globes are so accurately made that they are slightly depressed at the poles, thus making great circles passing through them slightly shorter than those that do not pass through the poles, but this difference is so slight that it may not interfere with your experiment.)

26. How to find the bearing of one place from another.

Bearing means the direction you would start in traversing the shortest route from one given place to another.

What is the bearing of the Philippines from Illinois? *The shortest route will follow the great circle connecting the two places.* Connect the two places with the string and note that the bearing is almost directly northwest while the direction is southwest. Point toward the Philippines in the line of the shortest route from Cincinnati. *Northwest.* What is the bearing of your antipodes from you? *Every bearing. Bearing and direction are the same for places at opposite points on the earth.*

Go from Illinois to the Japan Sea by shortest route, both on the 40th parallel north. The string sends your northwest through Alaska and Kamchatka. Get the distance by following the 40th parallel, cut off one-twelfth of the string and see if the remainder is long enough to measure the shortest route. Do navigators take advantage of shortest routes? *Yes, other things being equal.*

27. To prove that the distance measured on a great circle connecting any two opposite points is 180°.

Take half the string used in the 25th problem and note that it reaches from the north pole to the south pole; from London, the center of the land hemisphere, to New Zealand, the center of the water hemisphere; and from you to your antipodes. Show that it reaches from any point to its opposite point. The string is 180° long.

28. To prove that all great circles passing through a point also pass through the opposite point.

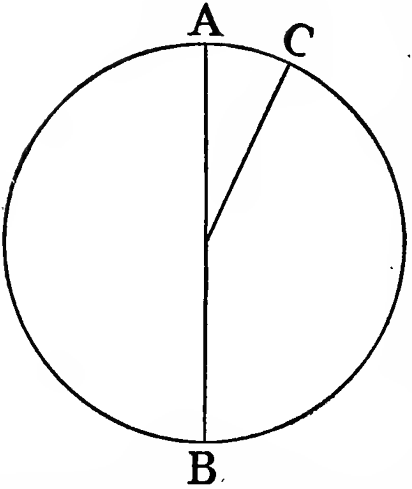
Take strings as in problem 25; tie them around the globe in great circles but passing through, say, London; but in different directions. They will cross at the opposite point, New Zealand. Regard the meridian circles as your strings and note that they pass through the opposite poles. Try it for any two opposite points. See if you can locate your antipodes with two of the strings.

29. To find the distance in miles from a given point opposite a place, say London, to any intervening point, say Costa Rica, Central America.

Is every other place intervening between any two opposite places? *Yes.*

The above problem is, How far is it from a place opposite London to Costa Rica?

With the string or a quadrant get the distance from London to Costa Rica, apply to equator (if string is used) and get degrees in length (72), subtract from 180° (108°), and multiply by 69 1-6 for statute miles, or by 60 for geographical miles.



Draw a great circle passing through your place A, through the place 20° from you C, and through your opposite point B.

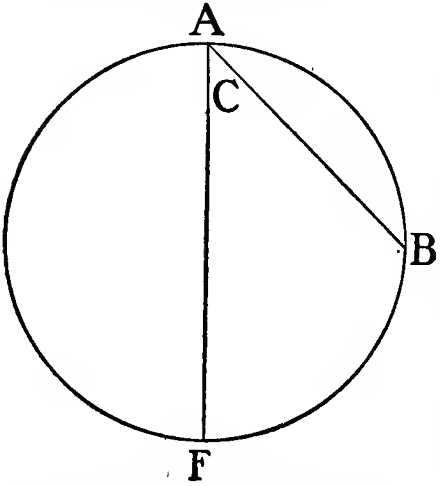
Question: How far from your opposite point to a place 20° from you measured on a great circle?

Arc ACB is 180° and arc AC is 20°. ACB 180 —AC 20=CB 160°; ×60 =9,600 geographical miles.

An arc is measured by the angle at the center made by the radii that subtend the arc.

30. To find how to point in a straight line through the earth from you to any given point.

An inscribed angle is in the circumference as C and its arc FB is measured by half the angle.



Let AF be the line of your body passing through the center of the earth, AB your arm, and C the angle your arm makes with your body.

Stand at the north pole and point toward the south pole. Evidently you are pointing past your feet and your arm makes no angle with your body.

Stand at the pole and point toward the equator. Let B be at the equator. ABF is 180°, BF is 90° and angle C is half of it, or 45°. Therefore your arm makes an angle of 45° with your body when you point directly at the equator from the north pole.

No difference where you are, point to a place 100° from you. ABF is 180° and. AB 100°. 180—100=80° for BF. But angle C is measured by one-half of BF and is 40°. Therefore your arm makes an angle of 40° with your body.

Suppose you are in Illinois, try to point directly toward London. Get the bearing of London from you with the string as in problem 25; also find the distance with string to be 55°. ABF is 180°. AB is 55°. 180—55=125° for BF. The half of 125 is 62½°, the angle your arm makes with your body.

Stand in Illinois and point in a straight line toward the Caspian Sea. Rectify the globe by hanging it up at Illinois and hold your arm parallel with the straight line that connects the two places. Point toward Peking, Good Hope, Cape Farewell, San Francisco, and Strait of Magellan. Estimate the angle your arm makes with your body in each case. Point toward your zenith, 180°; your horizon, 90°; half way between zenith and horizon, 135°; half way between horizon and nadir, 45°.

31. To find the direction in which a great circle passes through any two given points.

With the string as in problem 25, connect Illinois and the Caspian Sea and note that the string passes northeast and southwest through Illinois and northwest and southeast through the Caspian. Try Illinois and old Mexico; also any other two places.

32. To show the use of correction lines in original U. S. land surveys.

On the globe lay off a large tract of land with the points of the compass. It will be evident that the north boundary line of the tract is shorter than the south line and that the quarter sections on the north will have less than 160 acres. To avoid this, make jogs in the boundaries running north. Every few miles you must set the east line over to the east and the west boundary over to the west as you survey north. That is, you will have to "correct" the line. This accounts for the jogs in boundary lines running north and south.

33. To place the globe in the sunshine so that it will represent the natural position of the earth with reference to the sun.

Suppose you are at 40 north and 90 west. Suspend the globe at that point and hold it in the sunshine. The axis must be in a north and south plane with north pole inclined toward the north.

34. To show that twilight is shortest in the torrid zone.

Suppose you are at 40 north and 90 west. Suspend the globe at that point. Let the time be March 20th, days and nights equal, vertical ray of the sun on the equator.

Hold a lamp some distance west of the globe to represent the setting sun. Cut a strip of paper a little over 18 equator degrees wide and so paste it on the metallic meridian that it will make a band on it 18° wide and located on the side opposite the sun when the metallic meridian passes through your place. As twilight continues until the sun has passed 18° below the horizon, this paper strip locates the twilight zone. By tracing its outer edge on the globe you can see to what places twilight extends. Of course, you are holding the lamp in the plane of the equator because it is March 20th. The outer edge of the paper strip locates the twilight circle, which is a small circle as you see. The metallic meridian circle represents the day and night circle. The band between the day and night circle and the twilight circle is called the twilight zone.

Paste a bit of paper on your meridian (not on the metallic meridian) at the equator, one at Illinois, and one at the Arctic Circle. Paste three other bits on the globe under the outer edge of the twilight paper strip—that is, on the twilight circle. The first bits of paper are on the day and night circle and the last bits on the twilight circle. Now rotate the globe eastward but not moving the metallic meridian and note what paper strips emerge from the paper twilight band first; the one at the equator first and hence has shortest twilight; then the one at Illinois, and finally the one at the Arctic Circle. As 15° represents an hour, you can estimate the twilight for each place on March 20th. The zone being 18° wide at the equator, twilight will continue over an hour. Notice by the meridians and paper zone it is 1½ hours in Illinois and 3½ hours at the Arctic Circle.

See if the paper band gives twilight 18 latitude degrees beyond the north pole at this date; if so, the people there have twilight all night. So twilight becomes shorter as you approach the sun's vertical ray. On June 21st the twilight circle will extend 23½° still further over the poles or to 18+23½=41½ degrees. This would be in latitude 90—41½ or 48½° north. This would give Scotland and Ireland twilight all night.

The paper twilight band covers many more longitude degrees toward the north than toward the equator, hence the short twilight at tropics. Duration of twilight depends upon the time of year and latitude.

35. To find in what direction the rising sun will be seen on any day of the year.

The rising or setting sun is 90° from the observer. In what direction will the sun rise on March 20th? *Suppose you are 40 north and 90 west. By the analemma you find the vertical ray of the sun to be on the equator for that date. Lay a string on the equator and measure off 90°, hold one end at your place and shove the other eastward along the equator as far as you can. Note by your parallel the direction that the string leads from your place: directly east.*

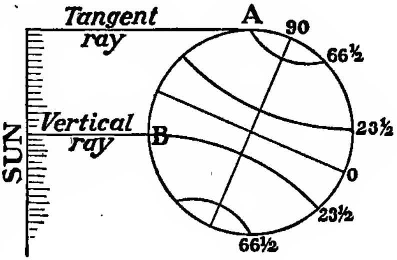
For sunset, you would move the string westward along the equator. Try it for June 21st. Place one end of the string at your place and the other eastward on the Tropic of Cancer. The string leads a northeast direction from you. Try it for other dates, using the analemma to get the latitude of the vertical ray.

36. To find the time of sunrise or sunset for any day in the year.

Suppose you are at 40 north and 90 west on May 20th. Where will the sun rise? The sun is 90° from your zenith at sunrise. By the analemma find the latitude of the vertical ray of the sun on May 20th to be about 20° north latitude. Take a string with two knots made in it at 90° apart, place one knot at your place and shove the other east along the 20th parallel as far as possible. This gives the location of the sun's vertical ray when it is sunrise for you. Bring the meridian of the place to the Metallic Meridian and place 12 of the time dial on that meridian. Now trace your meridian to the time dial to find it shows somewhat before 5 o'clock (4:45).

Get time of sunset the same way, except extend the string westward along the parallel.

37. To find the parallel beyond which no ray is falling for any day in the year.



The tangent ray is 90° from the vertical ray; that is, it is 90° from A to B.

No ray falls beyond what parallel on December 21st?

By the analemma the vertical ray of the sun is 23½° south latitude on December 21st, or on the Tropic of Capricorn; 90° north of this is 66½ north latitude, or on the Arctic Circle. The tangent ray does not fall beyond this on December 21st.

Try other dates and go 90° north of the sun's vertical ray.

38. To find the length of the longest day at any place within the frigid zone.

When does the northern boundary of Spitzbergen island have its longest day? With the metallic meridian get distance from the pole, 10°. If the sun is to shine on it all night its ray must pass over the pole, 10°. If its tangent ray is to pass over the poles ten degrees its vertical ray must be 10° north of the equator. By the analemma find day when the vertical ray reaches 10° north latitude in passing northward from the equator. This is April 16th. Notice by the analemma that the sun will finally return to the 10th degree of north latitude on August 27th. During all the time, from April 16th to August 27th, the sun has been shining on northern Spitzbergen island, 131 days. That is there are 131 common days in the longest daytime in northern Spitzbergen.

Show the longest day at the poles to be 180 days.

Table.

Giving the length of the longest day at different latitudes.

Latitude.		Length of day.		Latitude.		Length of day.	
°	'	H.	M.	°	'	H.	M.
8	34	12	30	63	22	20	00
16	44	13	00	64	50	21	00
24	12	13	30	65	48	22	00
30	48	14	00	66	21	23	00
36	31	14	30	66	32	24	00
41	24	15	00				
45	32	15	30				
49	2	16	00				
51	59	16	30				

Beyond this the days run from 24 hours to six months.

39. To find the equation of time, or difference in sun and clock time, on any day of the year.

Find the equation of time for February 11th.

Measure the distance from the meridian that divides the analemma to February 11th and measure off the same distance on the horizontal minute scale of the analemma and you will find it to be between 14 and 15 minutes. This means clock before sun, or nearly 15 minutes fast for that date, or that the sun is nearly 15 minutes slow for that date. If 8 o'clock sun time, what is the clock time? *Nearly 15 minutes after 8.*

Try it for December 24th, June 14th, April 16th and August 31st. You will find that the clock and sun are together on these dates.

On what dates may the clock be set with the sun dial? *On the dates just given and no others.*

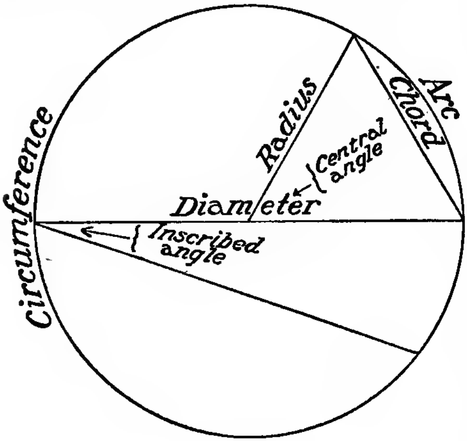
Why is the analemma made to bulge out sidewise? *For one thing you have just learned, this enables you to give the equation of time for any day.* Why does it extend from tropic to tropic? *So that it may locate the sun's vertical ray for any day in the year.*

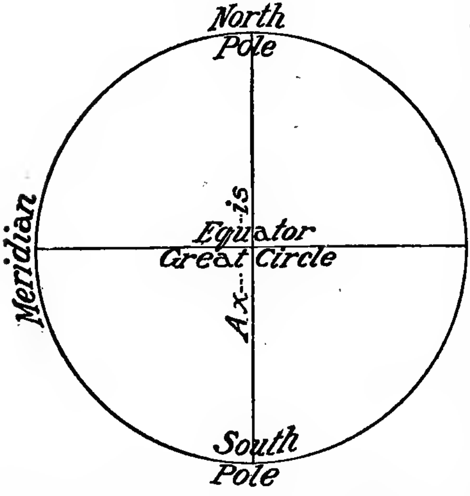
PART THREE

DEFINITIONS.

1. A *degree* is 1-360 of a circumference.

2. *Longitude* is the angular distance between two meridians—distance east or west of the prime meridian, and is measured on a parallel.





Latitude is the angular distance from the equator—distance either north or south of the equator and is measured on a meridian. The sensible *horizon* is in the plane tangent to the earth at the point of the observer — the circumference where the earth and sky seem to meet and is about three miles distant for a person six feet tall.

The *rational horizon* is parallel to the sensible horizon and divides the earth into two hemispheres.

East is the direction the earth rotates and *west* the opposite, both being at right angles to the north line.

North is the direction along the earth's surface toward the north star.

Direction of one place from another is determined by their latitudes and longitudes.

The *bearing* of one place (say London) from another (say Chicago) is the direction in which a great circle that passes through both points, crosses the horizon of the basal point (Chicago).

The *ecliptic* is the earth's path and the *plane of the ecliptic* is the plane in which the path lies.

The *zenith* is the point in the heavens directly overhead. You are between your zenith and the center of the earth. If two people have the same zenith, one must be directly over the other.

The *nadir* is a point in the heavens directly below the feet.

The *analemma* is a figure on the globe reaching from tropic to tropic, which gives the declination of the sun and the amount of time the sun is fast or slow compared with the clock.

The *theoretical date line* is the one that is 180° from Greenwich. The *practical date line* is near the 180th meridian and is the place where the new day first begins. The new daylight at different latitudes is not born on the same meridian. It is also the place where the day finally ends.

The *zodiac* is explained elsewhere. See index.

The *time dial* is the circular metal disk at the poles of the globe and its use is explained elsewhere. The 24 hour marks on it correspond to those of the clock and to the hour meridians on the globe.

Hour circles are the 24 meridians drawn on the globe. They are 15°, or one hour apart. They are designated on the metal time disk at the poles.

The *metallic meridian* is the meridian on the globe having degrees of latitude marked thereon and is really a meridian circle. In this work "the meridian" means "the metallic meridian."

Parallel lines are those that extend in the same direction. The parallels of latitude are often called the parallels. The meridians are not parallel.

An *angle* is the opening between two lines that meet.

The *poles* of the equator are the north and south poles. The poles of a circle are 90° from the circumference. The poles of the horizon are the zenith and nadir.

The *equinoxial points* are the two opposite points in the earth's orbit which are cut by the equator, or equinoxial.

The *solsticial points* are the two opposite points in the ecliptic 90° from the equinoxial.

Altitude. The altitude of a star (as the sun) is its angular distance above the horizon, measured on a vertical circle.

Declination. The declination of a star is its angular distance north or south of the celestial equator. It corresponds to *latitude* on the earth. See index to Part I.

Antipodes live on opposite sides of the earth.

Perioeci have same latitude but 180° difference in longitude.

Antioeci have the same longitude but opposite latitude.

Ascii have no shadow at noon; live within the Tropics.

Periscii are those whose shadow moves in a circle; in Frigid zone.

The earth *rotates* on its axis but *revolves* around the sun; but revolution also includes rotation.

The earth's *axis* extends from pole to pole and is always inclined 23½° from the perpendicular, or 66½° from the ecliptic.

Twilight is the period just before sunrise and just after sunset. The light you read by is the same as twilight because it is not direct. Particles of ice, dust, and possibly air reflect and refract the sun's rays to us until the sun has passed 18° below the horizon.

The *day-and-night circle,* or *circle of illumination,* is the circle made by the tangent rays of the sun; divides the earth into the light and dark hemispheres.

The *twilight circle* is 18° from the circle of illumination and on the side opposite the sun. It is 18° wide, measured on the great circles that cross it at right angles.

The *midnight sun* is the sun when seen 12 hours after noon.

The *cardinal points* are north, east, south, west.

Celestial sphere. The vast hollow sphere of the heavens. The part we see seems to be a great dome studded with stars.

The tropics. The tropical circles in which the solstices occur—23½° north and south of the equator.

Spheres. Right sphere, such as the people at the equator have, with north star in their horizon, and with horizon at right angles to the equator; parallel sphere, such as the people at the north pole would have, with north star in zenith and horizon parallel with the equator; oblique sphere, such as all others have, with north star between zenith and horizon, and horizon oblique to the equator.

Perihelion. The sun is in perihelion when nearest the earth.

Aphelion. The sun is in aphelion when farthest from the earth.

Apogee. The point in the moon's orbit which is farthest from the earth.

Perigee. The point in the moon's orbit which is nearest the earth.

The Celestial Equator. The same as the equator of the earth projected outward against the skies.

The Celestial North Pole. The same as the earth's north pole projected to the skies, the north star.

PART FOUR

FACTS AND EXPLANATIONS.

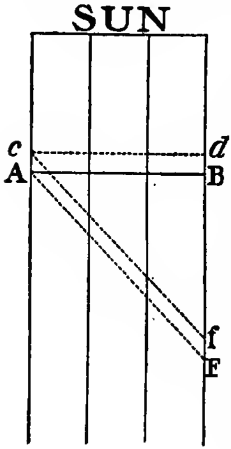
Distances. The sun is over 92,000,000 miles from the earth and the moon 240,000. The sun is so large that if it were where the earth is and the moon remain where it is, the sun's outer surface would extend not out *to* the moon's orbit, but 200,000 miles *beyond* it.

Weight. If you weigh 175 pounds here, you may tell your friends that you would weigh 5,000 pounds on the sun; but do not stop at the moon, for you would weigh only 30 pounds there and might be arrested for jumping into the third story windows. On the sun you could not jump at all, for you can not lift 5,000 pounds.

Rate of Movement. Telegraph as soon as you reach the sun, for we shall have to wait an hour and a quarter for the message to arrive. You may shoot a cannon ball at us if you like, for we will have 16 years to dodge it in; five years later we will hear the report. You can go on to the north star, if you like, and darken it, for we will continue to see it for 42 years after you hide it, and yet light travels the fastest of anything we know of.

Did you ever go 100 miles an hour in a race? The moon goes 2,000 miles an hour in her orbit, and the earth over 65,000. Tell the fellow with the 40-horsepower automobile that you are coasting through space at the rate of 65,000 miles an hour and that you have never experienced a single accident nor been put to any expense.

The Seasons. The causes of changes of seasons are the inclination of the earth's axis, revolution around the sun, rotation of the earth on its axis, and constant parallelism of axis.



Carry the globe around a pupil (the sun), omit any of the above named "causes" and note the effect on the seasons. Then drop the other "causes" one by one and note what the effect will be.

Heat. Let the vertical rays strike the earth at AB, and at a different time of year let the same rays strike the earth at AE. They are the same rays and convey the same amount of heat in each instance, but evidently they are spread over much more surface at AE. This must mean that a square foot of surface receives much less heat from the oblique rays than from the vertical rays. This accounts for the greater heat of summertime and also for the greater heat of tropical countries. Tangent rays, or those near them, give very little heat, or the north pole and south pole would take fire during the six months of continuous daytime.

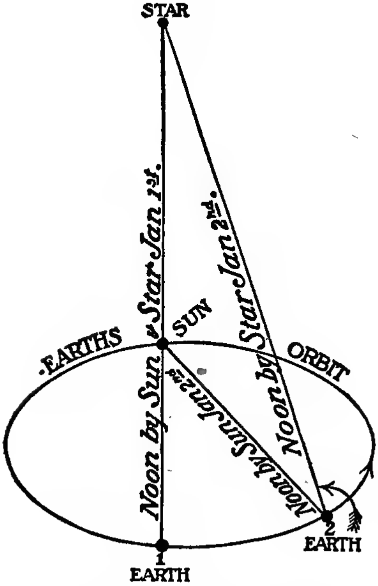
cd and *cf* represent the upper surface of the atmosphere, 50 miles above the earth. Show that the oblique ray traverses more air than the vertical ray before reaching the earth and therefore is relatively weakened. Above 50 miles the atmosphere has very little effect on the sun's ray.

Carry the globe around the pupil (the sun) and illustrate this; also call attention to the fact that the heat of summer time is partly due to the longer days.

Why is mid-winter weather not near December 21st when the sun is farthest south? *Because it takes the earth some time to radiate the heat accumulated during the previous seasons.*

Why is mid-summer weather not on June 21st—the time when the days are longest? *Because it requires some time for the sun to overcome the cold of previous seasons.*

Temperature increases about 1° for every 50 feet in descending below the surface of the earth. What is the temperature 100 miles below the surface?—sufficient to melt most solid substances? *Yes.* Does the earth's surface receive some of its heat from the interior? *Yes.*



The Sun Day Is Longer than the Star Day. (Figure exaggerated. From the earth the sun is seen in the opposite point in the orbit.)

Days and Years, Kinds of. Evidently you may have noon by a star as well as by the sun. See figure. Take noon of any date, as January 1st, and let it be noon by both sun and star as shown. The next day, January 2d, the earth will have moved onward. Let it again be noon by the star as shown. Evidently the earth will have to rotate further before it is again noon by the sun, as shown. So the sun day is longer than the star day.

The movement of the earth in its orbit and on its axis are both anti-clockwise. So the earth must turn a little more than once on its axis for a sun day and just once for a star day.

People finally invented clocks to give sun time, but could not get the clocks to keep with the sun, for the sun time constantly changed.

Tie weight to a string, swing weight around allowing string to wind around the finger, and observe the shorter the circle the faster the weight moves. So with the earth in its elliptical orbit, it swings faster in its orbit when near the sun, as on February 11th, when the sun is over 14 minutes slow. Look at the figure and see the farther the earth would go in a day the greater difference between sun and star time.

Finally the astronomers made out the sun's average time and let the clocks keep this.

Mean, or average, solar, or sun day	24 hours
Mean solar year	365 d. 5 h. 48 m. 48 s.
The siderial, or star, day	23 h. 56 m. 4 s.
The siderial, or star, year	365 d. 6 h. 9 m. 11 s.

The solar year is the time that elapses from the time the sun is in the vernal equinox until it returns to that place. The siderial year is the time that elapses from the time the sun occupies a certain position among the stars until it returns to that position.

For the sun day it was noticed that the earth made a little more than one rotation on its axis. In a year these little additions amount to one complete rotation on the earth axis; so the earth rotates 366 times in 365 days. Show this with the globe, letting the boy's eye be the sun and letting the sun be the star.

The Moon. It is over 2,000 miles in diameter and over 240,000 miles from the earth.

Movements:

Rotation on axis.

Revolution around the earth.

Movement around the sun with the earth.

For the moon, use the iron weight of the Johnston Suspension Globe, one hemisphere of which is white and one black.

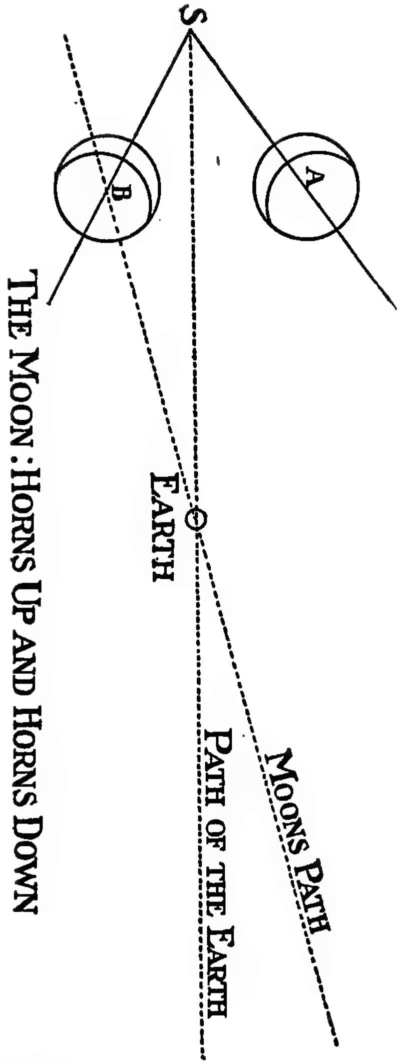
Illustrate the three movements. Keep the white side toward the sun, but imagine that it is moving around the moon, in about 29 days, for the moon rotates once on its axis in that time.

How much later does the moon rise every day? *About an hour.* Then in how many days will it again rise at same time it now does? That is, in how many days does the moon revolve around the earth? *About 24 (29½).* The moon revolves around the earth in 29½ days and rotates on its axis in the same time. If the moon did not move onward in its orbit, it would revolve around the earth in 27 1-3 days, her star time, or synodic revolution.

You know the orbit of the earth and that of the moon do not vary much from the same plane, because the moon at midnight and the sun at mid-day occupy about the same position. The sun's path is always in the ecliptic and the moon's path makes an angle with the ecliptic of only 5°.

If you see the moon, how locate the sun? *The light side is always toward the sun.* How often does the moon cross the sun's path? *Twice every 29 days.*

If a new moon should occur while she is "above" the sun's path what about the horns? *They would point "downward," "wet moon," the crescent will not hold water.* If the new moon has horns up, "dry moon," what do you know? *That the moon is "below" the sun's path, and the horns point "upward" toward the sun.*



THE MOON : HORNS UP AND HORNS DOWN

Using the Diagram.

Imagine yourself on the earth in the diagram looking at the sun at noon. Note its altitude above the horizon. Later the moon will come along near the same altitude, but may vary as much as five degrees above it or below it. At B the moon is below the point that was occupied by the sun. Note that the sun is inclined to shine on the "upper" half, thus leaving more of the lower half without illumination. This makes the horns point "downward" as shown, "wet moon." At A the moon has reversed conditions as shown in the figure. It is higher in the sky than was the sun and so the sun tends to shine on the "under" part, thus causing the horns to point "upward." As the crescent will now "hold water," it is said to be a "dry moon." Draw sun on blackboard and hold the "moon-ball" counter-balance accompanying the Johnston Suspension Globe, some distance above it. The sun shines on under side, making the illuminated cup, the white half, take such a position as to hold water, "dry moon." Incline the globe so as to show the crescent to pupil in the room. You can imagine the sun some distance behind the blackboard or hold the iron ball some distance in front of the board, but above or below the sun and easily show the crescent to pupils standing back in room. Now move the iron ball far to one side of the sun and cause the crescent to incline. Carry the iron ball to rear of room and show full moon; to sides of room and show first and last quarter.

In winter, how is the earth inclined? *Seems to be away from the sun at noon; that is, sun low in south.* Since the full moon is on the opposite side of the earth from the noon sun, is the earth inclined toward it in winter instead of away from it, as is the case with the sun? *Yes, the full moon will be high in winter and the noon sun low; and just the reverse in summer. The "moon runs high" in winter and "the moon runs low in summer," just the opposite of the sun.* Show all this with the globe and iron ball.

Phases of the Moon. Use lamp for sun, globe for earth, and iron ball for moon. Keep white side of ball toward the sun for the sun is what illuminates the moon. As the moon rotates in about a month, the sun sees all sides of it in that time and the white hemisphere of the moon should move around it (the moon) in that time.

Observe that when the moon is between the sun and earth, that the moon presents its dark side to the earth—the dark of the moon; pass it on anti-clockwise and we see a streak of illumination, a crescent moon, a new moon, which grows in width until it moves a quarter of the way around and is at the first quarter; another quarter and you have the full moon, with moon opposite the sun. Note that the sun and moon are on the same side of the earth at new moon and at the opposite sides of the earth at full moon. Pass the moon on another quarter and you see the last quarter. Lastly, move on to the dark of the moon or to the point of the new moon, the place of starting.

Evidently the moon has but one day in 29 of ours, for it keeps the same face turned towards the earth all the time and this would rotate it once on its axis in 29 of our days. Its night must be over 14 days long, and daytime, or sunshine, the same.

Carry the moon once around the earth and at same time revolve it once; that is, keep the same face turned toward the earth all the time.

Eclipses. Remember the ecliptic is the sun's apparent path through the sky and that the equator is inclined 23½° to it and the axis 66½°. The moon's path is not in the plane of the ecliptic, but crosses it at an angle of 5°. It must cross it twice in one revolution around the earth. If its orbit were in the plane of the ecliptic, show that there would be an eclipse of the moon at every full moon. The moon *is* in the ecliptic when it is crossing it, and when it happens to be crossing at the time of full moon, of course there is an eclipse of the moon; or, if it be crossing at the dark of the moon, the moon would eclipse the sun. Show that the three bodies must be nearly in the same straight line in order to cause an eclipse. Show that if they are not quite in a straight line that a partial eclipse may occur. Show that if you adjust the distances properly the moon may not be large enough to wholly eclipse the sun, but leave a ring of light around a darkened center.

If you wish the moon to darken, or eclipse, the sun, of course you will place the moon between the earth and sun. If you wish the earth to darken, or eclipse, the moon, of course you will place the earth between the sun and moon. Keep in mind that even the moon's light comes from the sun. If the sky were ceiled with moons our nights would be light with the reflected sunlight.

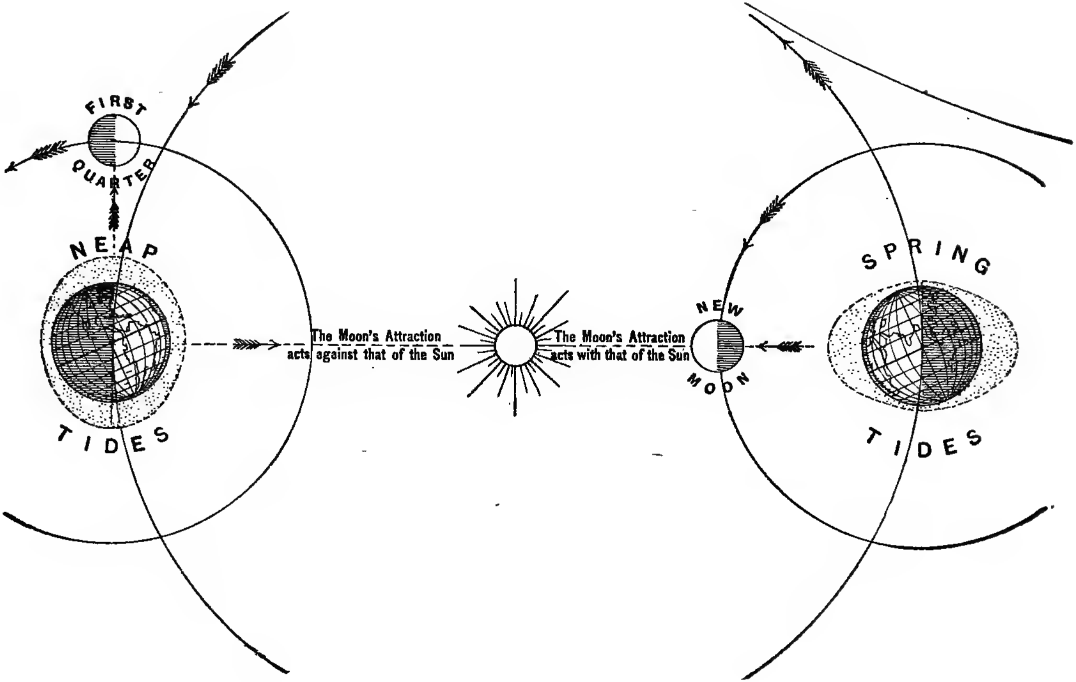
Show that an eclipse of the sun would occur near new moon and that an eclipse of the moon would occur near full moon.

The Tides. The alternate rise and fall of the sea level, the flow and ebb, together constitute the tides. They are due to the attractive force exercised by the sun and moon upon the earth. The effect of this attraction is to heap up the waters immediately following the disturbing body. But on the opposite side they likewise become heaped up; for, as the attractive power of a heavenly body diminishes with increased distance, the solid earth is more strongly drawn away than the waters on the opposite side, and they, so to say, are left behind. The moon exerts a much greater influence on the production of the tides than the sun; for, though its mass is excessively small in proportion, it is four hundred times nearer the earth.

The average interval between tides on successive days is nearly 25 hours, exactly the same as the interval between two successive passages of the moon across a given meridian. It seems that the moon is responsible for tides; does it not?

In the right-hand figure, the sun is in conjunction with the moon, the attractive power of each operating in the same direction; the waters are drawn toward the sun and moon and are there heaped up. On the opposite side they also become heaped up as shown. Similar tides will occur when the sun and moon are on opposite sides of the earth. So, *spring tides* occur at both new and full moon.

In the left-hand figure, the moon is in its first quarter, and is distant 90° from the sun. Their attractive powers are exerted in


FIRST QUARTER
NEAP TIDES
The Moon's Attraction acts against that of the Sun
The Moon's Attraction acts with that of the Sun
NEW MOON
SPRING TIDES

opposite directions and tend to neutralize each other. The moon raises the waters facing it and the ones opposite them while the sun's attraction works on the sides between those influenced by the moon. But the attractive force of the moon is that of the sun as 5 is to 2, so that in this case the amount of high water is the influence of the moon diminished by that of the sun. These are the *neap tides,* and occur when the moon is in her first and last quarters. On an average it is found that the spring tide is higher than the *neap* tide in the proportion of 7 to 3, so that the sea rises at new and full moon more than twice the height it attains at either first or last quarter.

After the moon reaches the meridian of New York, the tide comes lagging in about 8 hours tardy. If the ocean were over 14 miles in depth, and there were no sun tide and no continents or islands, the lunar tides could probably keep up with the moon and would flow regularly around the earth. As it is, the various complications make it impossible to give any reliable rule. The moon is almost continually crossing continents and almost continually starting new tides on leaving the continents. One of the fastest tides starts off the west coast of South America and crosses the Pacific in a northwesterly course at the rate of over 800 miles an hour in the early part of the journey.

An Ellipse. The earth's orbit is not quite a circle, but an ellipse. Take a string a yard long and tie its ends together. Hang the circular string on your two fore fingers, holding them about a foot apart and placing their ends against the blackboard. With a piece of crayon have some one describe as large a circular figure on the board as the string will permit. Place the sun at one of the foci, the point occupied by one of the finger tips. The figure is an ellipse and the sun is in one of the two foci.

The Noon Meridian. When the sun is on your noon meridian, where is the midnight meridian? *On the opposite side of the earth.* How many degrees apart? *180. The noon meridian and the midnight meridian make a great circle 90° from the day and night circle.* If you were on the Arctic Circle and looking at the midnight sun, would you be looking along your noon meridian? *Yes, but northward, and it would be midnight instead of midday. The noon meridian travels around the earth, the vertical ray always striking it.*

The Sun. The sun is composed of the same material as the earth, has an atmosphere, contains enough material to make over 1,200,000 earths, and at one time probably its circumference extended as far as the present orbit of its most distant planet. Its diameter is 852,000 miles.

It is thought that the sun rotates on its axis from west to east once in 25 days.

If you lived on the sun you would have to breathe iron, copper, lead, etc., for they compose, in part, the atmosphere. It is probably cooling off and in time will become the center of dead, silent worlds which may in time stumble together and start over again. The sun is simply one of the many fixed stars.

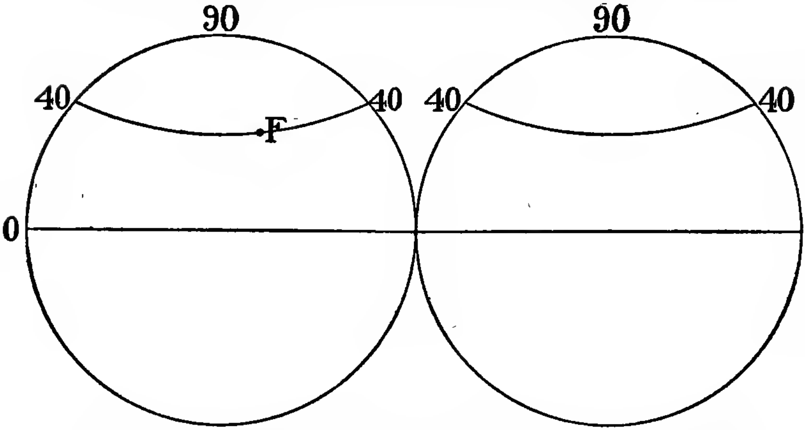
PART FIVE

MAKING AND USING A BLACKBOARD MAP OF THE HEMISPHERES

After using the globe until all are familiar with it, use it to teach how to draw a five-minute map of the hemispheres.

Examine the globe and see that the hemispheres are bounded by circles. If the hemispheres were separated and hinged and opened the circles would touch. Draw the outline.

Stand just far enough from the board so that you can reach the bottom and draw as large a circle as possible, holding arm straight and stiff. Draw another circle touching the first. A little practice will surprise you and bring excellent results.



Draw a point as F on the map and ask pupil how he would locate it. Suppose the pupil was on Mars, how would he direct his friend to find F? "Go to earth and hunt till you find F," is all he could say. Stick a pin in an apple and ask pupils to locate it. They fail because there is no starting place. They could tell how far north or south F is if there was any starting place.

How many degrees in a circle? *360.* What might we measure from? *We might start at the north pole, or from the south pole, or we might draw a horizontal line across the center or elsewhere and start from it.* All this is true. Finally agree to draw the equator and start from it. How far from pole to pole? *180°.* From equator to pole? *90°.* Where does F seem to be? *Not quite half way from the equator to the pole.* All right, call it 40° north.

Now the Martian can direct to better advantage: "Go to earth, thence north to the 40th parallel, and hunt along that line until you find F." Tell pupils that some geographers in the past had to decide the very questions that the pupils are now deciding.

Agree to call distance north and south of the equator, latitude. They need a word, so give it to them if they do not know.

How far around the hemispheres at the equator? *360°.* At the 40th parallel north, or at F? *360°.* Half way around? *180°.* Draw the other half of the parallel of F on the other circle. Call it a parallel because parallel with the equator. Show, by the globe, that these two halves are halves of the same parallel.

Should the parallel of F be drawn straight or curved? Let pupils look at same parallel on globe and satisfy themselves that it appears curved and so draw it. If it is to represent a globe it is to curve upward at either end. Agree to place the latitude, 40°, at the end of the lines on the map. Where is latitude placed? *On the sides of maps.* Examine the geography to see.

It may still take a long time to find F. What more is needed? *A point to start from in counting east and west.* Right. What may we count from? *We could start from any one of the four lines that connect the poles, or we could draw another line from pole to pole and count from it.* Let us name the lines that extend from pole to pole, meridians. Yes, we could use any meridian to count from. What shall we call the two halves of the earth? *Let us call the one to the right the Eastern Hemisphere and the other the Western Hemisphere.* In what hemisphere is F? *Western.* How are we to know what part of the earth is in the Eastern and what part in the Western hemisphere? *We can not know until we agree upon the matter.* Where shall we divide the earth? *Look on the globe and agree to divide through the oceans and not separate the grand divisions of land.* Find London, go 20° west. *This seems to be a good place to divide along the 20th meridian west of London.*

How shall we mark the meridian on west side of Eastern hemisphere? *20°.* Where shall we mark it? *Anywhere, but equator is the best place.* How mark the meridian that is on the other side of that hemisphere? *180°—20°*=160°. All right. How mark the two meridians bounding the Western hemisphere? *The same as the others, because they are the same lines, or same meridians.* Show this on the globe. We have naturally started to count east or west from what city? *London.* Since we might as well count from London as any place, let us draw the meridian of London, mark it zero on the equator, and count east and west around the globe from it. What shall we call distance east or west from the meridian of London? *Longitude.*

What lands do you intend to place in the Eastern Hemisphere and what in the Western? If you place the Old world in the Eastern, the New will be in the Western, and vice versa. Finally agree to place the Old world in the Eastern; but show by the globe that it could be placed in the Western by hinging the opposite edges of the hemispheres instead of the ones usually hinged.

Where is F? *In the new world; probably in North America.* Might each hemisphere select its own meridian from which to count longitude? *Yes.* What is the custom? *The London, or Greenwich, meridian, called also the Zero meridian and Prime meridian, is usually selected as the starting place.*

We have drawn the meridian of London by guess; now let us draw several meridians. How many degrees across the hemispheres on the equator? *360.* How many hours? *24.* How many hours across one hemisphere? *12.* One hour equals how many degrees? *360÷24=15°.* Let us draw a meridian for every hour. How many will it take? *As there are 24 hours there will be 24 meridians. We may call these meridians hour circles, for they are one hour or 15° apart; that is, the inter-meridian spaces are to be 15°.* How many inter-meridian spaces must we have in one hemisphere? *12.*

Let us draw the meridians in the Western Hemisphere first. Place a dot at the center of the equator and divide the space on either side of this dot into two equal spaces. You now have four equal spaces on the equator, so divide each one of these into three equal spaces and you will have twelve equal spaces, the required number. Draw the meridians from pole to pole through these dots. Treat the Eastern Hemispher in the same way without regard to the meridian of London.

Count the inter-meridian spaces. *24, which must be 15° wide each.* Count the meridians. *26.* Why? *Because you counted two of them twice.* The boundary meridians of one hemisphere are also the boundary meridians of the other. Where shall we number the meridians? *On the equator.* How many degrees of longitude may a place have? *Not over the half of 360, either east or west of London.*

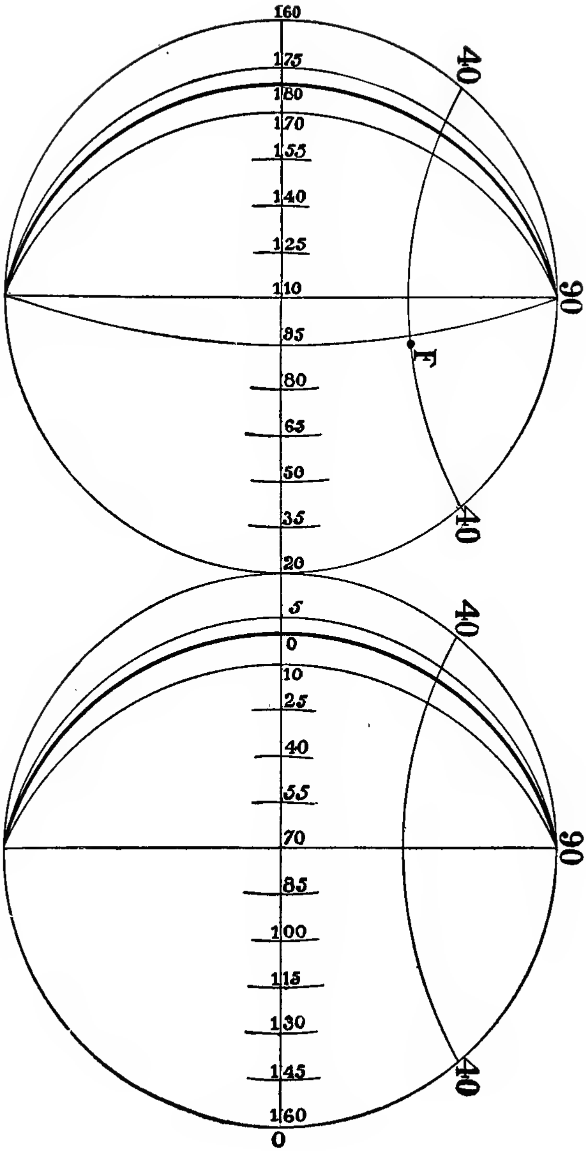
Where is the meridian of Greenwich? After numbering the meridians on the equator, draw the meridian of Greenwich in the proper place, if you have not already done so, and number it zero. How far is it from the Western Hemisphere? *20°.*

Let us call the meridian circle that divides the earth into the Eastern and Western Hemispheres, the *Dividing Meridian Circle,* and the half of that circle that is 20° west of London, the *Dividing Meridian.*

In numbering the meridians on the equator, did you run into any difficulty? Probably. You commenced at London and numbered west near 180° all right, but how far east did you go on the Eastern Hemisphere? *160°, but needed 20° more and had to find them on the western boundary of the Western Hemisphere.* The strip of 20° on the western boundary of the Western Hemisphere is in what longitude? *East.* But did you come to the 180th meridian in going east or west from London? *No, because that meridian is not one of the 24 that we drew; neither is the meridian of London.* Well, draw the 180th meridian in its proper place, and we may call it the theoretical *date line* if we choose.

On the globe, follow the zero meridian and the date line around the globe. Also follow the dividing meridian circle around the globe to see if it escapes all lands.

How far from London to the date line? *180°.* From the date line to the Eastern Hemisphere? *20°.* From the Eastern to the Western Hemisphere? *Zero degrees.*



F

Let us agree that F is 90° west. Now locate F definitely. *F is 90° west longitude and 40° north latitude.* How far is F from the Eastern Hemisphere? *70°, going east.* How far from west? *110°.* How far going north? *50°.* How far going south? *130°.* What is the nearest route from F into the Eastern Hemisphere? *North, even if the degrees of longitude are short at F.*

Where is latitude marked on all maps? *On the sides, but it is marked on the date line of the globe.* Where is longitude marked on maps? *At the top and bottom, but it is marked on the equator of the globe and of world maps.* See globe and geography.

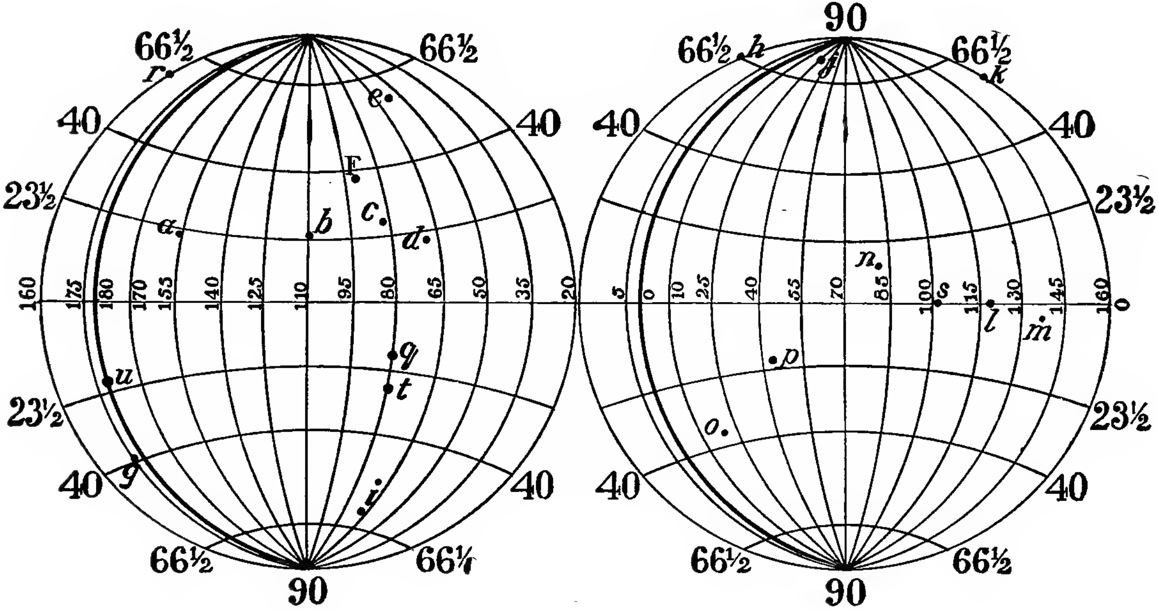
How far apart are the meridians? *One hour.* How many miles apart are they at the equator? *69 1-6 times 15°.* As the sun moves, how many hours apart are the meridians? *One.* How many hours are you (F) from the Eastern Hemisphere? *110÷15.* From the dividing meridian? *70÷15.* From London? *6.* Count on your map. From the date line? *6.* Count. Is the earth really divided? *No, but we divide it in map-making that we may view both sides at the same time.* We can see both sides of an apple at once if we divide it. Do globe-makers ever divide the globe? *Yes, for the same purpose.* The hemispheres may be hinged together. If you go from London to date line east, how far do you go in each hemisphere? *160° in Eastern and 20° in Western Hemisphere.* Suppose you go west from London to date line. *20 in the Eastern and 160° in Western Hemisphere.*

In what hemisphere is the zero meridian? *Eastern.* The date line? *Western.* The 20th meridian west? *Both hemispheres.* The 160th meridian east? *Both hemispheres.* Locate a place on the 90th meridian east or west, that is in both hemispheres. *Either pole, I suppose.*

Give the longitude of the dividing meridian. *20° west.* Of its opposite meridian. *160° east.*

Hold the globe with equator level with the eye. Do the parallels seem to curve farther from the equator to the right and left of your vertical ray of vision? *Yes, and you so draw them on the map, but in fact they do not so curve.* Do the meridians seem to converge at the poles? *Yes, and you so draw them, and they in fact do come to a common point at the poles.* Do the meridians seem to become closer together as you pass to the right or left on the equator from the vertical line of vision? *Yes, but they do not in fact; yet you can place them closer together as you pass to the right or left of the central meridian of each hemisphere, if you like, but I would not.*

Number the six parallels, including the equator and your own (F). Will latitude play any part in problems of longitude and time? *No..* How far are you from the Arctic Circle? Antarctic? Tropic of Cancer? Tropic of Capricorn? How much further are


66½
66½
r
e
40
40
F
23½
a
b
c
d
160
175
180
170
155
140
125
110
95
80
65
50
35
20
q
u
t
23½
40
g
i
40
66½
66¼
90
90
66½
h
f
66½
k
40
40
23½
n
5
0
10
25
40
55
70
85
100
s
115
l
130
145
160
0
m
p
23½
o
40
40
66½
66½
90

you from the Tropic of Capricorn than from the Tropic of Cancer? From the south pole than from the north pole?

(Give approximate answers, using the meridians nearest places named.)

1. When noon at *j*, give time at *e*.
2. When 11 a. m. Fri. at *n*, give time at *g*.
3. When 11 p. m. Fri. at *a*, give time at *g*.
4. When 3 p. m. Mon. at *l*, give time at *k*.
5. When 3 a. m. Tues. at *m*, give time at *k*.
6. When noon Tues. for you, give time at *k*.
7. When 4 p. m. Tues. at *c*, give time at *b*.
8. When noon Sat. at *d*, give time at *e*.
9. When noon Sat. at *k*, give time at *j*.
10. When noon Sat. at *k*, give time at *r*.
11. When noon Sat. at *a*, give time at *r*.
12. When noon at *t*, what is the time at *u*?
13. When noon at *s*, give time at *t*.
14. When noon at *a*, give time at *g*.

a. Sandwich Islands.
b. Lower California.
c. Florida.
d. Haiti.
e. Labrador.
F. You, 90° west.
g. New Zealand.
h. Iceland.
i. Cape Horn.
j. Spitzbergen.
k. Kamchatka.
l. Borneo.
m. New Guinea.
n. Ceylon.
o. Cape Good Hope.
p. Madagascar.
q. Panama.
r. Kamchatka.
s. Sumatra.
t. Cuba.
u. Fiji Islands.

Are *r* and *k* the same place? *Yes.* Through how many degrees of latitude is it noon at any moment? 180°, *or from pole to pole. The long days of the frigid zones are daylight rather than days.* Through how many degrees of longitude is it always noon? *The smallest fraction of a degree.* A step from the north pole would be in what direction? *South.*

In solving the above problems, either get the difference in longitude and reduce to time, or simply count the meridians using them as hour circles.